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The MERA Program

Project Catalogue 2008

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The MERA program

Project Catalogue 2008

Preface

The MERA program is a R&D program for manufacturing engineering, driven in cooperation between Swedish automotive industry and public financiers. The program started in September 2005 and finishes at the end of 2008. The program consists of more than 50 research and development projects with a total turn over of more than 800 MSEK. More than 20 research groups and more than 60 companies participate in the projects in larger consortiums.

In this project catalogue you will find descriptions of finished or ongoing projects within the MERA program (Manufacturing Engineering Research Area). The catalogue is published prior to the final program conference held in October 2008. In the texts, written by the project managers, you will find information on objectives, expected and achieved results, realization and contact information for each project. In the catalogue you will also find a short program description, including a brief history and realization.

The program has two main focus areas, manufacturing processes and manufacturing systems. The majority of the projects are focused on manufacturing processes. Examples are projects within tool manufacturing, welding and sheet metal forming. Within manufacturing systems project examples are conceptual plant development and lean-oriented projects. Some projects are focused on education within manufacturing engineering, such as assembly and metal cutting. The projects are all initiated from the automotive industry's needs and prioritized areas.

This catalogue intends to show the width and competence that Swedish researcher and Swedish industry possesses regarding manufacturing engineering. We would especially like to emphasize that joint research is an effective way to strengthen Swedish research and Swedish industry in a long term perspective. We hope that the results from the MERA program can benefit industry both inside and outside the program, and thus strengthen Swedish manufacturing industries' ability to keep and develop manufacturing in Sweden.

In autumn 2008 and spring 2009, results from the program will be presented at several occasions. Starting with the program conference in October, seminars for specific technological areas will follow. The seminars will be held at several locations around Sweden. Welcome!

October 2008

Göran Johnsson
Chairman, MERA program board

Margareta Groth
VINNOVA, MERA Program manager

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The MERA program

The MERA program is a R&D program for manufacturing engineering, driven in cooperation between Swedish automotive industry and public financiers. The program started in September 2005 and finishes at the end of 2008. The program consists of more than 50 research and development projects with a total turnover of more than 800 MSEK. More than 20 research groups and more than 60 companies participate in the projects.

Background

In October 2004 the Swedish government assigned VINNOVA to propose R&D programs within manufacturing engineering and vehicle-ICT for 2005-2008. The purpose was to facilitate a continued competitive automotive industry in Sweden through public and industry investments in research and development. The development of the R&D programs was conducted in close cooperation with Swedish automotive industry and researchers. The proposal was delivered to the government in March 2005.

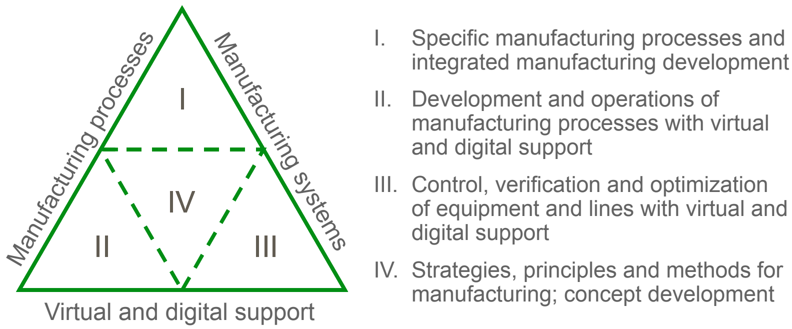
A program contract was signed between the Swedish government, the region Västra Götaland and the automotive industry in the summer of 2005, agreeing to run a R&D program focused on manufacturing engineering; the MERA program (Manufacturing Engineering Research Area). The overall program objective is to increase the industry's ability for competitive knowledge based manufacturing in Sweden. The program was started in September 2005 and ends December 2008.

Technical focus

During the program development, a survey was conducted regarding industrial needs. The survey points out long and short term needs. Based upon prioritization and synthesis, the general needs and the program's general direction was described in three main dimensions:

- Manufacturing processes
- Manufacturing systems
- Virtual and digital support

Needs and application areas are often combinations of at least two of these dimensions. Hence the program has a structure with Areas where multiple dimensions can be regarded, illustrated below.



Within the automotive industry there are three main application areas for manufacturing processes and systems: Component manufacturing, Body & cabin, and Assembly. The four areas above are used to structure manufacturing engineering issues within these different application areas.

Projects

More than 50 projects have started within the program. Most projects end in December 2008, some projects will continue into 2009. Aside from the five industrial parties, where FKG (Scandinavian Automotive Suppliers) are represented by a number of companies, more than 50 additional companies participate in different projects in the program. A number of research groups from 10 universities, a number of research institutes and regional research actors are active in the projects. Most of the projects are joint projects where three or more companies work together with one or more research groups. The projects have a total turnover of more than three quarter of a billion Swedish kronor.

Most of the projects are focused on developing existing and new manufacturing processes. A number of projects concerns simulation of manufacturing processes. There are also projects with a more conceptual focus and a more strategic perspective on manufacturing. The projects within the different areas co-operate through project clusters, based upon the three main application areas for manufacturing processes and systems projects.

Forms of cooperation

The program is broad and intended for research performers as well as industrial parties and other manufacturing industries. There are different activity forms to enable various activities and projects supported by the program:

- Strong research centers
- Joint projects between researchers and industry
- Innovative and coordinating environments
- Industrial continuous learning

The different forms of cooperation have supported both long- and short-term R&D and enabled both quick implementation projects as well as long term strategic research.

Organization

The program is managed by a board, with representatives from the contract parties. The board has an independent chairman, Göran Johnsson. The industrial parties in the program are AB Volvo, Saab Automobile AB, Scandinavian Automotive Suppliers, Scania CV AB and Volvo Car Corporation AB. The public financiers are Nutek, VINNOVA and Västra Götaland region, VGR. The program is operationally run by VINNOVA.

Industrial cooperation and clusters

In the program there is also an industrial coordination group that has the board's mission to contribute to coordination and optimization of the program. During the program the industrial coordination group has formed 10 Production Engineering Clusters for cooperation and critical mass within research, development and education. The Clusters cover main manufacturing as well as transverse production processes. The Clusters are controlled, co-ordinated and supported by the Strategy Governance Board and the Operative Management Group. Within the industrialization coordination group and the cluster structure the industrial program partners have identified common challenges and drafted a proposal for future programs in manufacturing.

Budget and financing

In the contract the parties agreed upon a shared financing where the industry should contribute with at least as much as the public funding. The public funding is 305 MSEK during 2005-2008. The total turn over of the program will thus be at least 610 MSEK over the period. At the end of the programme, industry will have contributed more than 500 MSEK, thus resulting in *a total programme volume exceeding 800 MSEK.*

Purpose and Objective

The primary goal of the program is to contribute to Swedish industry's ability to reach world-class competitiveness within knowledge-based manufacturing, by creating:

- premium academic R&D within manufacturing disciplines,
- a research agenda at universities and research institutes that is formed together with industry, and executed by integrating industry and academia in R&D projects and programs.

The program will be evaluated based upon following part objectives:

- Turn over of industrial manufacturing related R&D in Sweden.
- Degree of co-operation within the automotive industry and between industry and academy (universities and research institutes).
- Volume of project results that are used to improve the participating companies manufacturing systems.
- Volume of successfully finalized demonstration projects
- Number of academic exams within relevant areas
- Number of new educations for students, research students or industry employees.
- Number of industry employees that have gained significant improved competence through the program.
- Number of patents and published industrial standards.

Each activity and project has also concrete, quantitative objectives that are related to the content of the specific project. In addition, the program is evaluated on qualitative objectives such as:

- Effect on Swedish technology development and competitiveness of Swedish manufacturing systems.
- Improvements on manufacturing engineering education, due to the MERA program, within relevant MSc programs.
- Impact on global companies' decisions regarding keeping R&D resources in Sweden and placing R&D responsibility for specific technology areas in Sweden.

In the short term, the program should contribute to improved co-operation between researchers and companies, leading to continued improved competitiveness. In the long term the program should contribute to an ensured competence supply and creating internationally competitive research and development.

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Organization

The program is managed by a board, with representatives from the contract parties. The board has an independent chairman, Gšran Johnsson. The industrial parties in the program are AB Volvo, Saab Automobile AB, Scandinavian Automotive Suppliers, Scania CV AB and Volvo Car Corporation AB. The public financiers are Nutek, VINNOVA and Västra Götaland region, VGR. The program is operationally run by VINNOVA.

In the program there is also an industrial coordination group that has the board's mission to contribute to coordination and optimization of the program.

Program board

Chairperson	Göran Johnsson
Scandinavian Automotive Suppliers	Henry Mellgren
Saab Automobile AB	Freddy Ploj
Scania CV AB	Björn Bäckström
Volvo Car Corporation	Nader Asnafi
Volvo Powertrain	Urban Wass
Nutek	Lars-Håkan Jansson
VINNOVA	Ulf Holmgren
Västra Götalandsregionen	Bertil Törsäter

Industrial coordination

Scandinavian Automotive Suppliers	Henry Mellgren
Saab Automobile AB	Lennart Malmsköld
Scania CV AB	Sven Hjelm, Björn Holmgren
Volvo Car Corporation	Nader Asnafi
Volvo Powertrain/AB Volvo	Magnus Granström, Johan Svenningstorp
VINNOVA, adj.	Magnus Wiktorsson

Cluster structure

Strategy Governance Board

FordonsKomponentGruppen	Henry Mellgren,
Saab Automobile AB	Freddy Ploj
Scania CV AB	Björn Bäckström

Volvo Car Corporation	Mats Tharing & Nader Asnafi
Volvo Powertrain/AB Volvo	Katarina Lindström
Swerea IVF	Mats Lundin

Operative Management Group

Scandinavian Automotive Suppliers	Henry Mellgren
Saab Automobile AB	Lennart Malmsköld
Scania CV AB	Sven Hjelm, Björn Holmgren
Volvo Car Corporation	Nader Asnafi
Volvo Powertrain/AB Volvo	Magnus Granström
Swerea IVF	Jan Sjögren

Kluster Ledning och koordinatorer		
Kluster	**Industriella Kluster Ledare**	**Koordinatorer**
Component Manufacture	Sven Hjelm, Scania	Tero Stjernstoft, Swerea IVF
Body & Cab Manufacture	Lars-Ola Larsson, Volvo Cars	Elisabeth Sagström, Swerea IVF
Surface Treatment & Paint	Micael JO Larsson, Saab Automobile	Lars Österberg, Swerea IVF
Assembly	Ingemar H Nilsson, Saab Automobile	Björn Langbeck, Swerea IVF
Geometry & Quality	Björn Matsson, Volvo Cars	tbd
Automation & Control Systems	Stefan Axelsson, Volvo Cars	tbd
Logistics & Materials Handling	Henrik Brynzer, Volvo Cars	tbd
Virtual Engineering & MDM	Johan Svenningstorp, AB Volvo	Rotates between Chalmers, KTH and Högskolan i Skövde
Production Management	Lena Moestam, AB Volvo	tdb
Education	Tommy Nyström, Scania	B-G Rosén, Sw. Production Academy

Operational program management

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	Magnus Wiktorsson
	Bengt Larsson
The program management:	MERA@VINNOVA.se

MERA conference 2008

Manufacturing of Components

OPTIMA – Optimised materials for robust manufacturing

Understanding the machinability of materials of toady and tomorrow is a key factor for efficient and robust manufacture of advanced components. The overall aim of this project is therefore to generate new knowledge regarding the relation between material, component realisation (casting) and machining. Through the co-ordination of competences and resources from different areas, a number of fundamental issues are addressed where focus is placed on the correlation between material microstructure and machinability. Experimental studies in laboratories and real industrial environment are combined with theory and modelling. The project also addresses the development of a strategic network and technical/scientific co-operation, which means that the Swedish automotive industry will have direct access to relevant research resources at universities and research institutes.

Objective

The robust machining of powertrain components is key factor for the productivity and competitive strength of the automotive industry. OPTIMA or OPTImised Materials for robust machining shall generate basic knowledge for the relation between material behaviour and machinability and provide the conditions for robust machining processes. The overall aim is the generation of new knowledge regarding the correlation between machining – material- product realisation (casting or other processes). This is achieved in two ways:

- Tests in production environment through close co-operation with material and tool suppliers where results can be more or less directly implemented
- Model experiments, analyses, modelling/simulation to establish correlations and fundamentals of the machinability of materials of interest, involving dedicated efforts by PhD students and senior scientists at universities and research institutes

OPTIMA covers a wide range of different materials, from cast iron to high strength alloys. This ensures both the breadth of knowledge and the development of generic understanding.

Specific goals are:

- Increase in efficiency by 3-5 % within manufacturing lines supported by project results

- A strong network for R&D of relevance for manufacture of advanced components using advanced materials
- New knowledge regarding interaction between component realisation (e.g. casting), machining and material
- Decreased lead time and lowered costs when introducing new materials in products
- Specifications for robust machining through the improved knowledge gained
- Strengthening of suppliers and increased competitiveness through knowledge dissemination from the project
- Basis for recruiting scientists (e.g. new PhDs) to industry
- New knowledge regarding metal cutting experiments and evaluation of difficult-to-cut materials
- Increased critical mass regarding PhD students among universities and research institutes

Results and Deliverables

OPTIMA is organised as four parallel sub-projects: OPTIMA-nodular cast iron, OPTIMA-CGI, OPTIMA-case hardening steel, OPTIMA-high strength alloys. Scientific and technical issues addressed are:

- Influence of material microstructure on machinability
- Cutting mechanics, forces and thermal impact
- Control of machining processes through the tailoring of the actual cutting processes and quality assurance in every stage of the processing chain
- Wear mechanisms for inserts and the optimisation of cutting processes and tools
- Prediction of cutting processes and wear
- Quality control of casting process regarding material (CGI, nodular iron) and product properties

Common to all the mentioned issues is their importance for the robust machining and quality assurance of advanced components in e.g. casting. The project is currently in a very intense phase with respect to technical and scientific progress. The companies contribute with production oriented R&D, services and material, while the universities take in parallel specific responsibility for laboratory studies and tests as well as development of evaluation methods. Below, a short summary of selected results is enclosed.

OPTIMA-nodular cast iron addresses the impact of material on machinability in real component manufacture at Bror Tonsjö, Kode, and Volvo Car Corporation, Floby. A larger production follow-up has been done by Chalmers together with these production sites. Basic knowledge has been developed that concerns factors that affect the machinability. Subsequent in-depth evaluation has followed one line related to materials aspects and one line concerning cutting tool aspects. The goal with OPTIMA – nodular cast iron is to increase productivity with 20-30 %, a goal that is realistic to achieve.

Compact graphite iron or CGI has better mechanical properties than ordinary grey iron, but combined with reasonable thermal conductivity. However, CGI is much more difficult to machine than grey iron. This is the reason behind *OPTIMA-CGI*. Test materials for a unique experimental test matrix (16 variants of CGI) has been developed and produced through significant efforts by Volvo Powertrain, Scania CV, etc together with Sintercast and Novacast. The pre-work has involved experiments by Swerea-SweCast. In-depth studies concerning the microstructure and properties of cast CGI are done in parallel by JTH, Jönköping, and Swerea-Swecast. Figure 1 below shows the microstructure of a CGI-material with micro-cells. Figure 2 illustrate data from laboratory cooling experiments. GM Powertrain Sweden contributes with extensive modelling and simulation work related to component realisation.

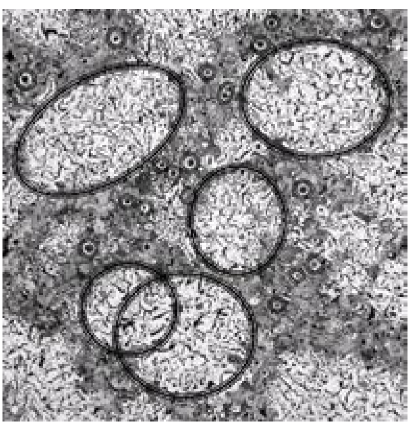


Figure 1. Micro-cells in CGI.

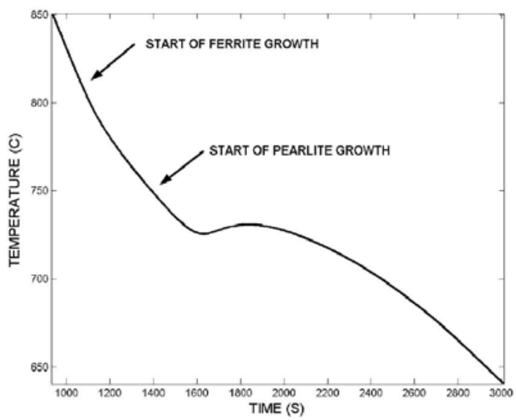
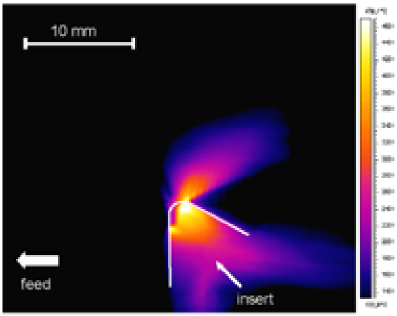
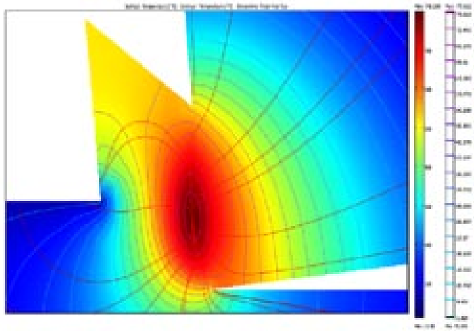


Figure 2. Cooling curve transformation of CGI.

The physical conditions in machining of CGI are studied in detail using special samples in addition to the evaluation of the machinability of the mentioned 16 variants of CGI produced. The work includes special tests (Quick-stop), chip and contact area studies as well as evaluation of tool wear. The work is carried out by a twin-PhD team at KTH and Chalmers. For each PhD student, licentiate degree is planned before end of 2008. Measurement of cutting forces and temperatures are combined with the evaluation of surface characteristics of CGI. Figure 3a shows temperature measurements and Figure 3b shows the simulated image of temperature distribution in CGI machining.



a)



b)

Figure 3. IR-image and simulated temperature distribution in CGI machining.

A component-like test part has been designed and produced in different CGI variants (see Figure 4). The reason for this is to be able to mimic the machining of real components and real machining operations.

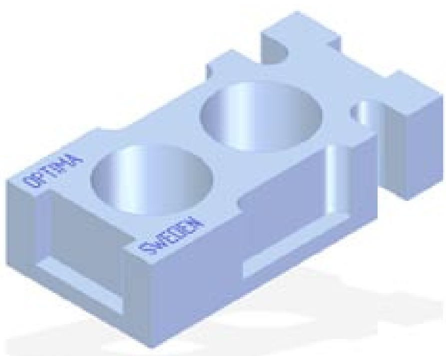


Figure 4. Component-like test part designed and produced within OPTIMA.

Another activity aims at find recommendations for the performance of machining systems and equipment so that machining of CGI can be done in an optimised way. This problem is addressed by a PhD student ant KTH.

Theoretical and practical conditions for direct observation of the role material behaviour in machining are addressed in *OPTIMA-high strength alloys*. This part also includes the development of knowledge regarding simulation of material-tool interaction in metal cutting. The simulation work is done at University West, while the aspects of material structure and machinability are dealt with at Chalmers. The work includes model laboratory experiments with force and temperature measurements. The PhD student has gained practical experience at Volvo Aero Corporation, who also takes active role in the experiments at Chalmers. Production follow-up studies are done by an industrial PhD student at Siemens, Finspång. A thorough evaluation of incoming material and machinability in real production is carried out. The test matrix for the laboratory test at

Chalmers has been developed through specially designed heat treatment procedures. A licentiate exam is planned for end of 2008.

The wear on cutting inserts has been found to be almost independent of grain size for the materials studied. The simulation work at University West focuses on the chip formation mechanisms and agreement with experimental results is found. The PhD student defended his thesis in September 2008.

OPTIMA-case hardening steel focuses on the correlation between material microstructure, machinability and distortion. The objective is to understand how case hardened steel shall be specified to have a robust and predictable processing with respect to these issues. The work is divided in such way that Chalmers works with the correlation between material microstructure and machinability, while KTH addresses the correlation between microstructure development and distortion in heat treatment.

The Volvo machinability test is applied to rank the machinability of differently produced microstructures. Componenta has together with Chalmers and Scania realised the test material. The evaluation works well and basic knowledge regarding the effect of pearlite structure has been depicted. Examples of machined structures are shown in Figure 5. Chip-breaking tests have also been done by Sandvik Coromant. The PhD student at Chalmers will realise her licentiate degree during the fall of 2008.

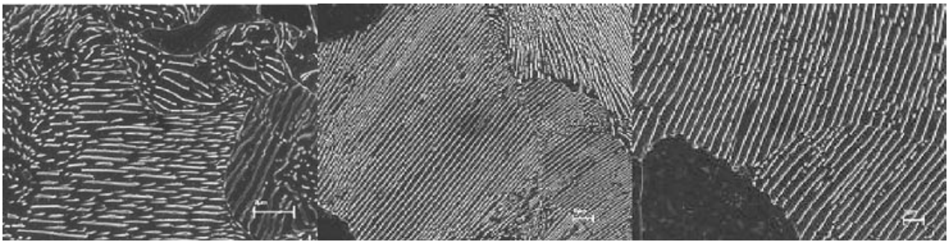


Figure 5. Examples of microstructures for which machinability has been tested using Volvo standard machinability test within OPTIMA-case hardening steel.

Project Realisation

The project is run as an integrated project with four different sub-projects in parallel. Industrial co-ordinator is Volvo Powertrain AB through Jonas Möller. Project co-ordination and scientific leadership is held by MCR (Metal Cutting Research and Development Centre) at Chalmers through Lars Nyborg. An overall co-ordination group has following members: *Jonas Möller (chairman), Volvo Powertrain AB, Karl-Gustav Lurén,Volvo Powertrain AB, Uf Bjarre, Scania CV AB, Sven-Eric Stenfors, Scania CV AB, Håkan Sterner, Volvo Car Corporation, Raymond Reinmann, GM Powertrain Sweden AB, Göran Sjöberg, Volvo Aero Corporation, Anders Lenander, Sandvik Tooling, Lars Nyborg, Chalmers.*

The critical mass of research efforts related to machining-related and product realisation is strengthen through the close co-operaton between Chalmers-MCR, KTH-DMMS, University West, School of Engineering Jönköping University (JTH) and Swerea SweCast AB. This is shown in Figure 6. Besides 7 academic PhD students, there is one industrial PhD student at Siemens. The steering group chairmen and sub-project leaders are given below. The project co-ordinator is also member of all steering groups.

Sub-project	Steering group chairman	Sub-project leader
CGI	*Kent Eriksson, Volvo Powertrain*	*Magnus Wessén, JTH* (casting) *Hans-Börje Oskarson, Chalmers* (machining)
Case hardening steel	*Karl-Gustav Lurén, Volvo Powertrain*	*Uta Klement, Chalmers*
Nodular iron	*Håkan Sterner, Volvo Cars*	*Kenneth Hamberg, Chalmers*
High strength alloys	*Henrik Runnemalm, Volvo Aero*	*Göran Sjöberg, Volvo Aero*

Sub-project	**CGI**	**Nodular iron**	**Case hardened steel**	**High strength alloys**
Chalmers MCR	1 PhD student + scientists	Senior scientists	1 PhD student + scientists	2 PhD student + scientists
KTH DMMS	1 PhD student + scientists		1 PhD student + scientists	
Jönköping University	1 PhD student + scientists			
Swerea-SweCast	1 scientist + staff			
University West				1 PhD students + scientists

* including one industrial PhD student at Siemens, Finspång.

Figure 6. PhD students and efforts at different universities and research institutes.

Den overall research plan of OPTIMA follows the description below in Figure 7. Through initial studies increased knowledge is gained regarding the correlation between machining, product realisation and material. Based on this knowledge, studies are focused on the general optimisation of machining processes. Finally, the knowledge gained is supposed to be tested for specific operations in industrial environment to clarify the possibilities and constraints regarding these operations. The concept of c-operation is illustrated in Figure 8.

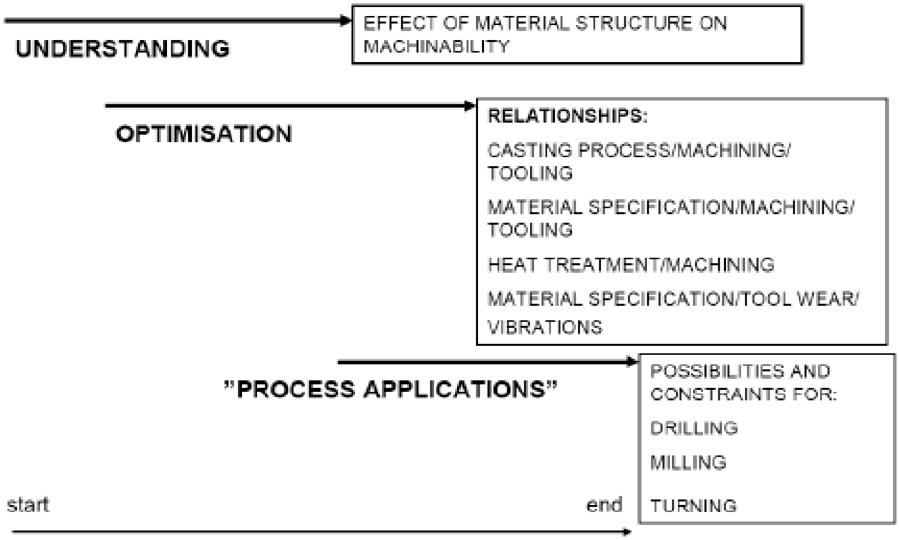


Figure 7. Overall strategy of OPTIMA.

Figure 8. Industrial and academic production-oriented research within OPTIMA.

Project Outcomes

The OPTIMA-project gathers a critical mass for co-ordinated R&D in the area of metal cutting with particular reference to materials and product development. This critical mass is built on the participation of universities, research institutes, core automotive industry stake-holders and other strategic industrial partners. This mixture is necessary for the joint effort of OPTIMA. Further synergies are also created, such as the co-operation with other projects within as well as outside MERA. Expected outcomes are:

1. Improved specification of current material – less production problems and improved productivity
2. Knowledge regarding machining of new materials – more efficient introduction in real production in future
3. Improved methods and reduced time for machining tests – shorter lead times in R&D
4. Increased robustness in manufacturing through common technology platform
5. Doubling of critical mass of academic research through the establishment of several PhD projects
6. Increased competence and experience broadly within different organisations to set-up, monitor and perform integrated R&D across different organisations

Interaction has been established with MERA-KUGG (transmission components research) and MERA-VBC (heat treatment research). Via Chalmers-MCR, KTH-DMMS, University West and Jönköping University, OPTIMA connects as well to the undergraduate education at these universities. Swerea-SweCast AB connect to professional development regarding product realisation and casting.

To strengthen synergies within OPTIMA internal workshops are held. Researchers within OPTIMA participate also at yearly conferences as the MERA conference, the Swedish Production Symposium, cluster conferences, international conferences, etc, which means that knowledge and results are also communicated to a wider audience.

International contacts are kept within Europe and USA in particular. The first choice is mandatory to find opportunities in EU-programmes. The second choice is a key factor for international co-operation with important stake-holders. Some examples of such contacts are Georgia Tech and Ohio State Univ. These contacts are now further developed through a new VINNPRO-project.

Participating Parties and Contact Persons

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Robotised Metal Building by Melting Wire, RMS

A novel and flexible method for building metal geometries directly from CAD-data is being developed. The technology is based on robotised laser welding with filler wire. The laser power source is a 6kW fibre laser, and the flexibility is obtained through e.g. robot- and manipulator movements and possibility to use different welding optics. Off-line programming develops nominal welding parameters and robot paths, while sensors measure real process outcome, and a control system compensates if there are discrepancies between desired values and on-line measurements. The operator monitors the process at a distance using an operator interface with camera representations and presentation of measured data. The operator can manipulate the process parameters from this interface if needed.

Objective

Development of the RMS-process to facilitate for CAD-data based automatic and efficient metal building of geometries for prototypes, new manufacturing and repairs.

Results and deliverables

Industrial results:

- Development of the RMS-method – an operator friendly laser cell is developed and implemented at Production Technology Centre (PTC) in Trollhättan. It contains cameras and sensors for communication with the operator and possibilities for the operator to interfere with the process.
- Process parameters are developed for aero space material and tool steel
- The process is demonstrated on industrially interesting components
- A system architecture is developed for the whole chain *CAD → robot paths → controlled process → geometry*
- The cooperative work between industry and academy is strengthened
- Increased understanding of the possibilities and limitations with increased grade of automation in this type of industrial application
- Strengthened regional, national and international networks within automation and production

Academic results:

- A PhD-student employed with estimated licentiate degree before end of project
- Development of a generic measurement system with a data base of analysis off- and on-line of process data, and thereby increased knowledge of the RMS-process
- Sensor and control system developed for on-line control of desired geometry (height/width) and for off-line analysis
- A user interface developed for automatic generation of robot paths for building arbitrary geometries
- Increased understanding of production issues among the control engineers at the university
- Publications:
  - Heralic, A., A.-K. Christiansson, et al. (2007). *Automation of robotized laser metal-wire deposition*. IASTED International Conference on Control and Applications, Montreal, Canada.
  - Heralic, A., A.-K. Christiansson, et al. (2007). *Freeform fabrication using laser metal-wire deposition*. Swedish Production Symposium. Gothenburgh, Sweden.
  - Heralic, A., M. Ottosson, et al. (2008). *Automation of a Robotised Metal Deposition System using Laser melting of Wire*. 18th International Conference on Flexible Automation and Intelligent Manufacturing (FAIM 2008), University of Skövde, Sweden, Runit AB, Skövde
  - Heralic, A., A.-K. Christiansson, et al. (2008). *Control Design for Automation of Robotized Laser Metal-wire Deposition.* 17th IFAC World Congress, Seoul, Korea.
  - Heralic, A., M. Ottosson, et al. (2008). *Visual feedback for operator interaction in surface modification by means of robotiser laser metal deposition*. 22nd International Conference on Surface Modification Technologies. Trollhattan, Sweden

Project realization

The work is performed in a close cooperation between the partner companies and academia, and a laser cell has been installed by Innovatum, where the experiments are performed. University West has within the project designed an operator control panel so that the process can be efficiently monitored with the aid of cameras and sensor signals. Process development is performed using stored measurement data, and static and dynamic models can be developed. These models build a basis for development of controller algorithms. In parallel with these on-line efforts off-line programs are developed for automatic generation of robot paths to cover the geometries, using appropriate welding parameters. The different system parts communicate over the industrial fieldbus Profibus, and the programming environment LabVIEW is used for data acquisition, control activities and monitoring.

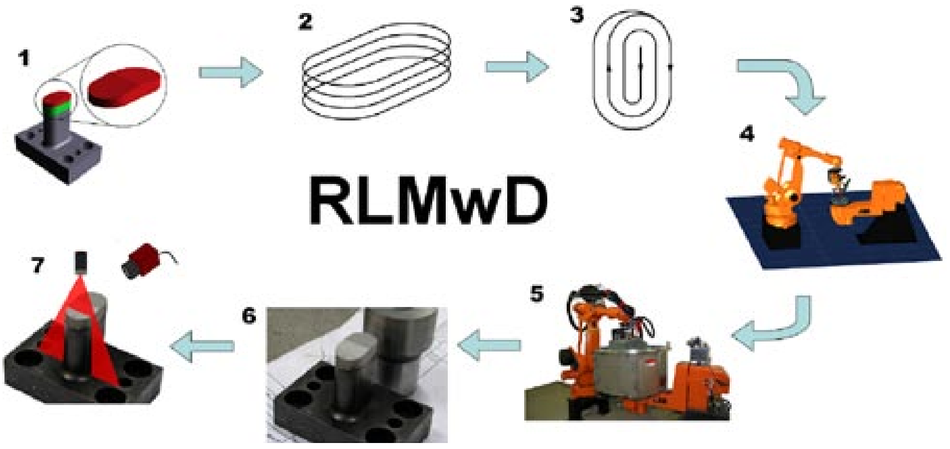

Illustration of the working procedure for the RLMwD-process (Robotised Laser Metal-wire Deposition)

The technical solution is illustrated in the figure above:

1. The process starts with CAD-data for the geometry to build.
2. An off-line procedure is developed in the project. It slices the geometry into layers. The size of these depends on material and the process window chosen by the operator in a menu system.
3. Robot paths are generated automatically so that the layers are filled one after the other.
4. The robot paths are simulated and observed to assure that no non-allowed situations occur. The robot program and nominal process parameters are thereafter downloaded to the physical robot.
5. The laser welding process builds the geometry through controlled laser power and wire feed rate based on sensor data. The operator is guided through camera information and sensor data on a control panel, where he also can perform control actions. All data is stored in a data base.
6. Depending on the demands of the surface structure, some machining might be needed
7. Finally a 3D-scan is performed to verify that the geometry.

Some examples

Left: Bosses built on a component with aerospace material
Right: Hardfacing in tool steel on a stamping tool (to be machined)

The RMS-project has focused on two applications, geometries based on aerospace material and repair of stamping tools in tool steel. The process is at date semi-automatic. In the examples given in the figure above the operator intervened manually with the aid of on-line information from the developed measurement system. Full automation with height and width control has been performed on straight builds of several beads side by side and several layers on top of each other.

Some identified difficulties and limitations

The project has identified some difficulties and limitations that need to be treated before the process is fully automatic and industrially robust suitable for arbitrary geometries and materials, e.g.

- Automatic path generation of arbitrary geometry – what geometries are needed? What parts need to be treated as special cases and what can be generic? How to take the process development data into account? What limitations in the process equipment can be solved?
- Control of width and height – What is meant by "built width and height"? What should be measured as width and height for arbitrary geometry?
- Process development – How to speed up the determination of process window for arbitrary material?

There are issues that need to be solved, and the answer to some of these will be given at project end. The RMS-project has been successful and deliveries are according to plan. A semi-automated process is developed to date, and is estimated to reach full automation for industrial implementation within 2-3 years.

Project outcomes

The RMS-process shows a large potential regarding metal building of geometries for prototypes, new manufacturing and repairs. Some areas of interest involve:

- Aero and aerospace industry – the process is considered as an important sub-process for new design solutions, e.g. to substitute large castings with fabricated alternatives with different added features
- Land based vehicles – manufacturing of prototypes and new production, e.g. by using high value materials in critical areas and thereby decrease material and manufacturing costs.

The project parties have gained a deep knowledge in the process, and the project idea has been spread through the many visitors to the RMS-cell at the Production Technology Centre. Both industry and academy have shown strong interest in the project, and been impressed by the progress made. The co-location at the Production Technology Centre is beneficial not only for the cooperation between the parties, but also for spreading of information to a broader public.

Participating parties and Contact person

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SAAB Automobile AB	Karl-Gunnar Larsson
Högskolan Väst	Anna-Karin Christiansson
Permanova Lasersystem	Lars-Erik Jansson
Volvo Powertrain	Jack Samuelsson
UGS Svenska AB	Lars Sveding
COOR Service AB	Jerker Andersson

Establishment of and research activities at VBCentrum (The Swedish Heat Treatment Centre), MERAVBC

"Establishment of and research activities at VBCentrum (Heat Treatment Centre)", MERAVBC, will be performed in two main parts:

- **The start and set-up of the collaborative workspace VBCentrum ("Heat Treatment Centre")**
- **Project activities within MERAVBC comprising three projects:**
  - **When is tempering needed?**
  - **Carburizing, new materials and an improved process**
  - **Induction hardening**

VBCentrum was established in 2006 with ten industrial companies as members together with Swerea KIMAB and Swerea IVF. The overall objective of VBCentrum is to establish a long-term and sustainable co-operation and research activity between R&D performers and companies active within the heat treatment area.

The collaborative workspace of the VBCentrum is strengthened through the fact that the work will generate increased co-operation between industry, institutes and universities in research and development within the area of heat treatment, with a continuous build-up of competence. The emphasis of the research activities, mainly performed as project work, will be put on how design, materials and process will have an impact on the lead time, cost, and performance of heat-treated products, and also of the environmental impact.

Objective

The aim of the project MERAVBC is to establish a strong and sustainable VBCentrum in order to achieve the expected results mentioned below. This will be done by creating a collaborative workspace and by R&D project activities. A base is created with the necessary conditions for a long-term establishment of VBCentrum.

The overall aim of VBCentrum is to contribute to making the competence of the Swedish heat treatment business reach world class. Among the technical activities of VBCentrum the emphasis is laid on the impact of design, materials and process on the lead time, cost and performance of products where heat treatment is part of the production sequence

Results and deliverables

The collaborative workspace:

- University education ”Industrial heat treatment of steel” developed. Two course's have been held at Royal Institute of Technology during the period with VBC-members as teachers.
- Four new member companies have joined VBC.
- One diploma work has been accomplished and two new ones are on-going projects.

Project ” When is tempering needed?”

- Testing and evaluation of rotary bending, surface fatigue, fracture toughness, torsion fatigue and impact toughness is taking place. Trends are that for certain cases it’s more favorable, with respect to material fatigue strength, to eliminate tempering.
- The potential risk of Hydrogen embrittlement is investigated. Testing finalised, evaluation is taking place.

Project ” Carburizing, new materials and an improved process”

- New steels with lowered tendency for surface oxidation. Test gears have been produced
- Tests with vacuum carburizing and different gas quenching parameters during martensitic transformation have been performed. The objective is to study how the temperature path below Ms-temperature influence fatigues performance. Testing is taking place.

Project ”Induction hardening”

- A study of how cooling parameters affect hardness and residual stresses is on-going.
- A project where FEM-simulation is used for studying cracking risks has just started
- A litterature study of how surface fatigue properties can be optimised will start during October.

Project realization

The collaborative workspace:

- National and international conference - and area monitoring is an important activity. Information dissemination is made to VBCentrum-member companies and to “Värmebehandlingsforum (Heat Treatment forum)” members. “Värme behandlingsforum"is an information network that is run by Swerea IVF since 1997, but is now integrated in VBCentrum.

- The education “Industrial Heat Treatment” was held as a part of the course "High performance steel and other alooys" at the Royal Institute of Technology. VBC-members were responsible for four out of ten chapters. One occasion was held at Bodycote in Älvsjö and one at Scania in Södertälje.
- Diploma works. The graduate students are placed at one of the member companies but are also in contact with other participants in VBC.

Project

- Manufacturing of test samples are done by companies
- Testing is perfomed at institutes and companies
- FEM-simulation of induction hardening using Sysweld.
- Regular project meetings via telephone. When necessary physical meetings.
- Twice a year, we have physical meetings where all projects are gone through

Project outcomes

Thanks to the ”MERA-program” Värmebehandlingscentrum has been established, with adequate research volume, and has been active during three years. The member companies pay a membership fee based on company size and desired share they want to participate with. The membership fees are used to i.e Program Research projects that is decided by the members by a voting process.

Members in VBC are: Scania, Volvo, Atlas Copco Secoroc, Finnveden Powertrain, EFD Induction, Teknoheat, AGA, Bodycote, Parker Hannifin, Ovako, SKF, StressTech, Uddeholm Tooling, Sarlin Furnaces, Swerea Kimab och Swerea IVF.

Participating parties and Contact person

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Bodycote Värmebehandling AB
EFD Induction AB
Finnveden Powertrain AB
Ovako Steel AB
Parker Hannifin AB
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Induction hardening of carburized parts for high performance vehicle components

In the project has one combined heat treatment process been studied with aim to increase fatigue performance of power train components. The result became that the combined process has a potential to increase the performance with at least 30 %. The total cost increase became for a specific industrial case 6-8 %. This increase can be considered to be justified especially if expensive new - or redesign can be avoided.

Objective, Results and Deliverables

The project's aim has been to study how a combination of two different types of heat treatment processes influences the fatigue performance of power train components. The two processes were case carburizing and induction hardening. Both these are common to use when high requirements on material strength are desired for e g powertrain components in vehicles as for example shafts and gears. Normally are two different types of steels used at the different processes, case hardening steels with carbon content of approximately 0.2 %. At induction hardening the so-called quench and tempering steels are used with carbon content approximately 0.4 %.

Earlier surveys done by other groups of researchers have in certain cases demonstrated that performance increases in the magnitude of 15-30 % is possible to achieve through such process combinations. In these surveys, one has however in several cases used unconventional processes and materials. In this project, it has only been used existing, conventional heat treatment equipments and steel types. In order to study the result after case carburizing combined with induction hardening has experiments been made on both test samples and a power train component. In addition to fatigue testing have also hardness, microstructure, residual stresses and retained austenite contents been evaluated.

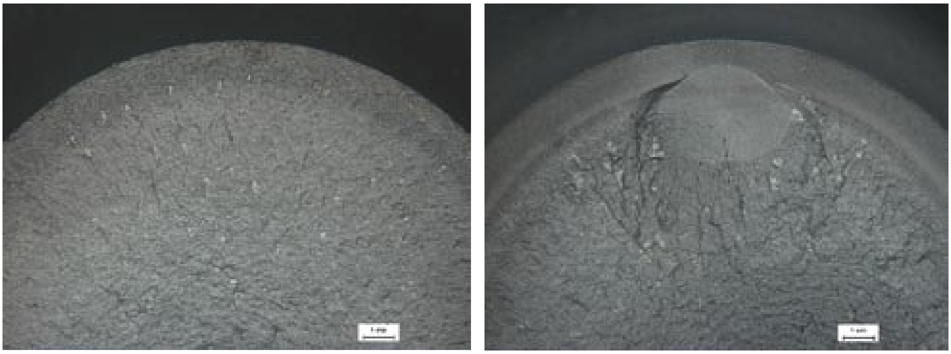
The fatigue testing that was made on test samples showed that the surface's fatigue strength increased compared with case carburized reference samples with at least 30 % when case carburizing combined with induction hardening combined with double-shot-peening was done. In these cases no crack initiation in the surface could be observed. It will however be emphasized that test samples where case carburizing combined with double-shot-peening received approximately 40 % higher fatigue strength, but these had crack initiation both in the surface and below the hardened layer. The reason to that initiation take place just below the hardening zone is that the material here has are softer in combination with unfavorable residual stresses. After surface hardening compressive stresses are normally received in the surface, which is positive in order to with-stand fatigue, but these compressive stresses are counter balanced by tensile residual stresses in the region just below the hardened layer, which can influence fatigue performance negatively, among other things depending on how the loading profile is acting in each case.

It has also been found in the experiments that the high compressive stresses normally expected, was not received in the surface layer after induction hardening. The reason to this is not fully determined. The most plausible reason is that the surface carbon content, as been received after carburizing, been on such a level that the retained austenite that remains in the surface layer after cooling not give sufficient volume expansion off the martensite in the surface. This is normally one of the main effects of induction hardening of conventional steels that gives build up of high compressive residual stresses.

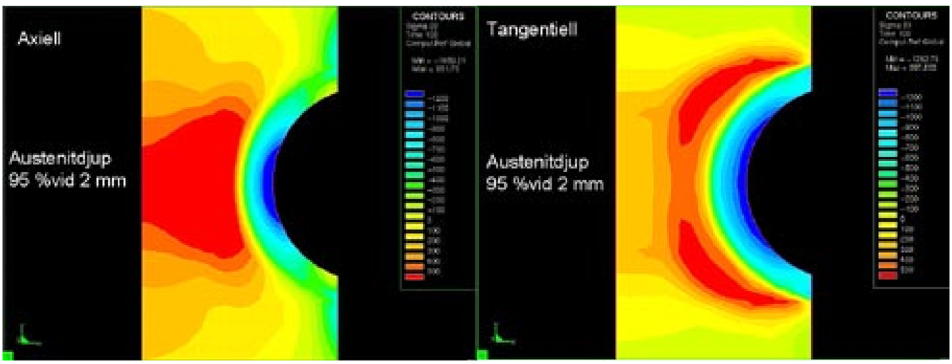
In the case with the component, where a medium carbon steel was used, any improved fatigue strength could not be demonstrated. This despite that higher hardness and more favorable microstructure was received. A reason to that the results did not become better is probably that the steel type that was used contained a high level of inclusions which in combination with high hardness can lead to early crack initiation in the surface due to increased notch sensitivity. One could also see that one after only induction hardening of a not carburized component received the expected compressive residual stresses in the surface. For the carburized components only low compressive residual stresses was received and this independent on the hardness before induction hardening. (what could have an effect since plasticizing of the area below the hardened zone at fast heating rate processes, such as induction hardening, is another mechanism that contributes to how compressive residual stresses are built up in the surface).

All in all it is however concluded that a combination of case carburizing and induction hardening has potential to give increased fatigue strength in the surface of a component. How big this increase is will be tested in a new project where the hardened zone will be made to last deeper and where tempering will be made at lower temperature in order to give higher strength (hardness) deeper down below the surface. Carburizing will be done with a carbon potential that is lower than 0.6 % in order to give lower retained austenite content in the surface and thereby higher compressive residual stresses. These measures should then result that crack initiation is moved out to the surface, where initiation and growth is hindered and becomes delayed due to the built-in compressive stresses.

In the production economic assessment that was done for the component case it could be established that the total cost increase in the specific case was in the order of 6-8 %. It can in certain cases be motivated with such a cost increase, if it for example means that vehicle weight can be reduced or that customer or law requirement can be contained, especially if it means that costly re-design can be avoided.



Left: Surface initiated fatigue cracking of conventional case carburized test sample
Right: Crack initiation below the hardened layer after hardening acc to process combination



Calculated residual stress field in notch of the test sample

Participating parties and Contact person

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Leif Nordfelt	Atlas Copco Secoroc AB
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Krister Johansson	Scania CV AB
Kristian Berggren	EFD Induction
Erik Sandqvist	Scania CV AB
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Influence of surface characteristics on the result of nitrocarburising

Nitrocarburising is a heat treatment method, which more and more is used for components, which have to meet requirements of low friction, increased wear resistance, increased fatigue and improved corrosion resistance. By the subsequent oxidizing process the components get an attractive appearance, which today is extensively in demand both for quality and aesthetic reasons. Less energy is consumed than, for example, when case-carburising as the temperatures are lower and the process time is shorter.

The condition of the surface prior to nitrocarburising is of vital importance. Residues, from e.g. cutting fluids/-oils and cleaning agents, and passive areas may prevent the surface reaction and growth of compound and diffusion layer. This results in areas with no layer build up, uneven layer thickness and discoloured surface appearance. In this study different cutting fluids and cleaning agents have been evaluated in order to determine the influence on the compound zone. Tests have been performed to study how relevant factors describing the initial surface characteristics influence the result of nitrocarburising.

Focus has been on analysing the influence of chemicals, deriving from earlier operations such as machining and cleaning. Different commercial cutting fluids, oils and cleaning agents have been evaluated in order to determine the influence on the compound zone. Specific constituents of the chemicals have also been studied.

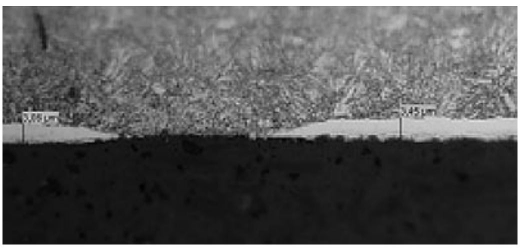
Objective

The aim of the project is to study how and at what levels relevant factors describing the initial surface characteristics influence the result of nitrocarburising. Focus has been on analysing the influence of chemicals, deriving from earlier operations such as machining and cleaning.

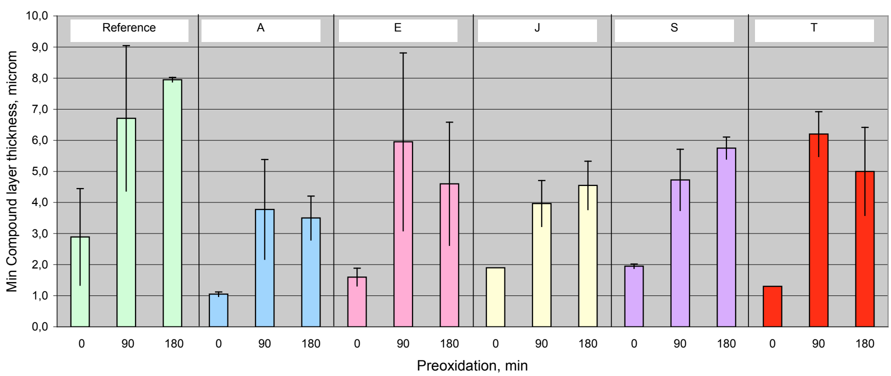
Results and deliverables

- Preoxidation improves layer formation (see figure below)
- 180 min preoxidation compared to 90 min, 400 °C resulted in no further significant influence on layer thickness ä possible to optimise pre-oxidation
- Residues from chemicals cause problem with layer formation, passive areas

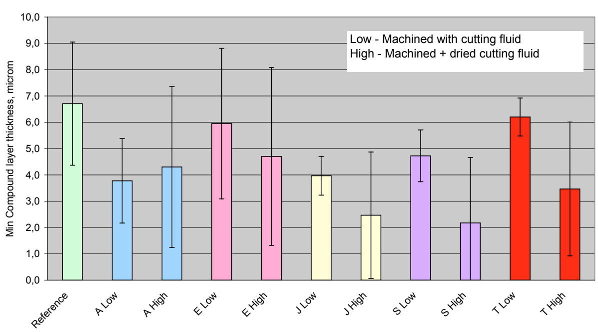
- The cutting fluids influences on layer build-up: some more than others
- Negative influence was noticed for S, P (oils) and Ca, B (emulsions)
- Some detergents have a negative impact on the layer formation
  - Negative influence was noticed for phosphates, surfactants and contaminations
- Plastic deformation gives a reduced compound zone thickness
- Electrochemical passivity measurements: Method to distinguish between newly grinded, aged and contaminated surface, but not how clean the surface is.
- Eddy current measurements can be used for evaluation of layer thickness after nitrocarburising



Nitrocarburised layer with passive area without compund zone.



Influence of pre-oxidising on compund layer thickness for tested cutting fluids.

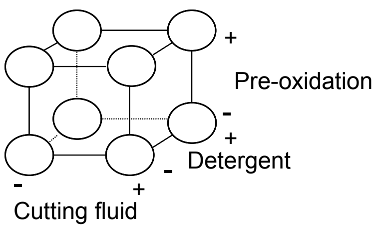


Influence of different cutting fluids on compound layer thickness after nitrocarburising. A, E and J are emulsions and S and T cutting oils. Pre-oxidising at 400 °C.

Project realization

A literature study was performed showing that the preparation of surface and the condition of the surface prior to nitrocarburising is of vital importance. After that a series of tests were performed.

Design of Experiments is used to identify the most important factors describing the surface characteristics, and how they influence the result of nitrocarburising. The factors are varied on two levels and the sample series are carried out according to DoE. Tests have been performed with samples prepared with special chemicals as well as five different combinations of commercial cutting fluids/oils and detergents. The used combinations are the same as are used in production at five different plants.



	Low	**High**
Detergent	None	Dried
Cutting fluid	Machined	Dried
Preoxidation	none	90 min

DoE-experiments to study the influence of cutting fluid, detergent and pre-oxidising.

Steel samples, in steel 42CrMo4, were turned with the cutting fluids or oils to be tested.

After machining remaining liquid was blown off with air. For high level according to DoE the detergents and/or cutting fluids were let to dry up on the surface.

The nitrocarburising process was performed at 580 °C, 45 min, in an atmosphere of 35 % NH3, 5 % CO2 and 60 % N2. Pre-oxidising was performed in air at 400 °C in 0,90 or 180 min.

After nitrocarburising the compound-layer thickness and hardness were evaluated. Focus has been on analysing the thinnest compound-layer thickness, since it is the presence of such areas that has to be minimised.

For surface analyse, GDOES (Glow Discharge Optical Emission Spectrometry) was used after machining, preoxidation and nitrocarburising for elemental depth profiling.

A test series was performed in order to evaluate the influence of the specific chemical constituents, e.g S, P and B, on the compound layer build-up. Two levels for each specific chemical were tested; “normal” corresponds to a level that can be used in commercial products, “high” is ten times the value for “normal”.

Project outcomes

This study has shown that in order to minimise the presence of passive areas, followed by insufficient compound layer, the surfaces should be as clean as possible before nitrocarburising. Residues deriving from earlier machining operations may cause passive layers. It is important to control and follow-up the cleaning process and if necessary use additional rinsing steps.

Participating parties and Contact person

AGA Gas AB
Atlas Copco Secoroc AB
Bodycote Värmebehandling AB
Nordic Lubricants AB (Castrol)
Finnveden Powertrain AB
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Modern Metal Cutting Education

Good knowledge in machining technology is very important for the Swedish manufacturing industry and for recruiting of qualified engineers. Today the courses that are used in the university are built on an old concept from around the years 1970 to 1980. Courses on a high level for professional learning in machining technology are of the same position. This project has created a modern and an interesting education in machining for spreading knowledge to students in the undergraduate programs and for professional learning. The course has been designed by the university partners together with the industrial partners.

Motivation

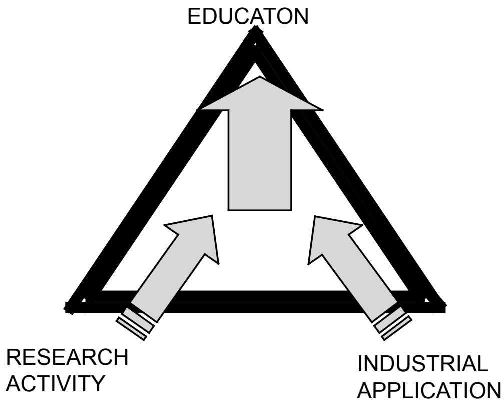
Increase the knowledge of machining technology for new engineers and already professional engineers in the Swedish manufacturing industry. Make Metal Cutting interesting and popular.

Expected results

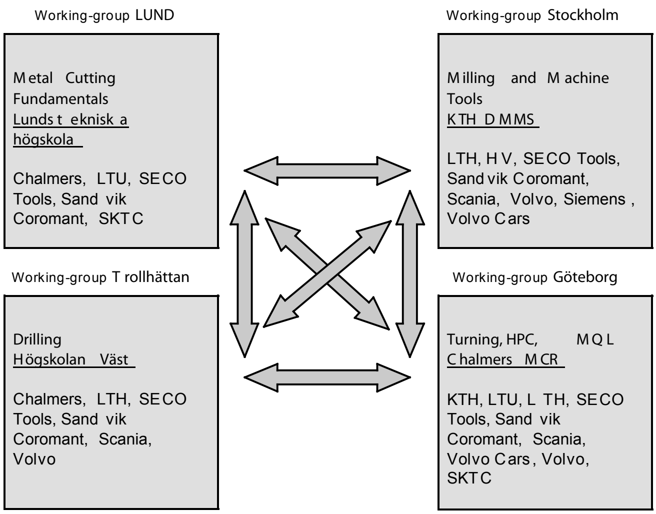
1 Design an interesting and a modular course concept at different knowledge levels in machining technology that are built on the latest and most modern knowledge in the area of machining technology.
2 Use modern simulation techniques for visualisation in part of the course.
3 Create a network between universities and between universities and industry for knowledge development in the area of machining technology.
4 Establish a network organisation between the partners for continued development of courses in machining technology in the future.

Project realization

The development of the course has been done in four different working groups with Chalmers, KTH, LTH and Högskolan Väst as working group leaders. The groups are connected to the research activities on those four universities.



In these working groups the industry partners are active. The Chalmers MCR is the project leader Hans-Börje Oskarson) and a steering group for the project is chaired by Scania (Kurt Forsberg).



Homepage

http://msu.iip.kth.se

Results

So far the working-group has done two *mappings* in the area of:

- existing courses in Metal Cutting
- the needs for the industry in machining technology

Metal Cutting *terminology* and units fore this education are decided.

An **education concept** is decided. The Modern Metal Cutting Education is modulated and consisted of three different knowledge levels:

Level 1: Four different modules. Each 4 hours.

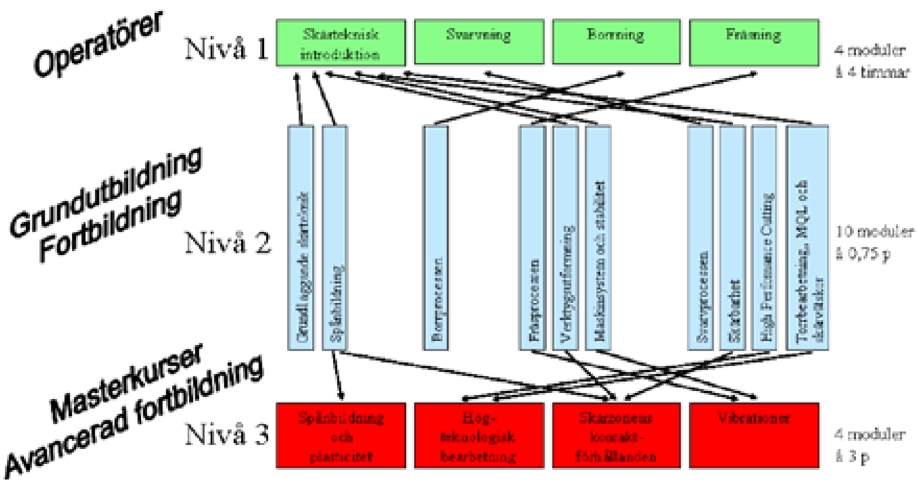
Target group: Professional learning: Machine Tools operators.

Level 2: Ten different modules. Each 0,75 ECTS.

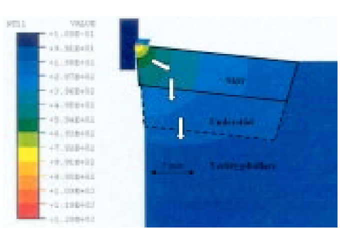
Target group: Students in the undergraduate programs. Professional learning: Production Engineers.

Level 3: Four different modules. Each 3 ECTS.

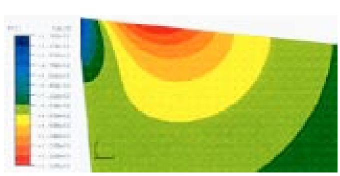
Target group: Students in the masters and graduate programs. Professional learning: Production Engineers.



Beräknad temperatur i skärverktyget m.h.a. FEM

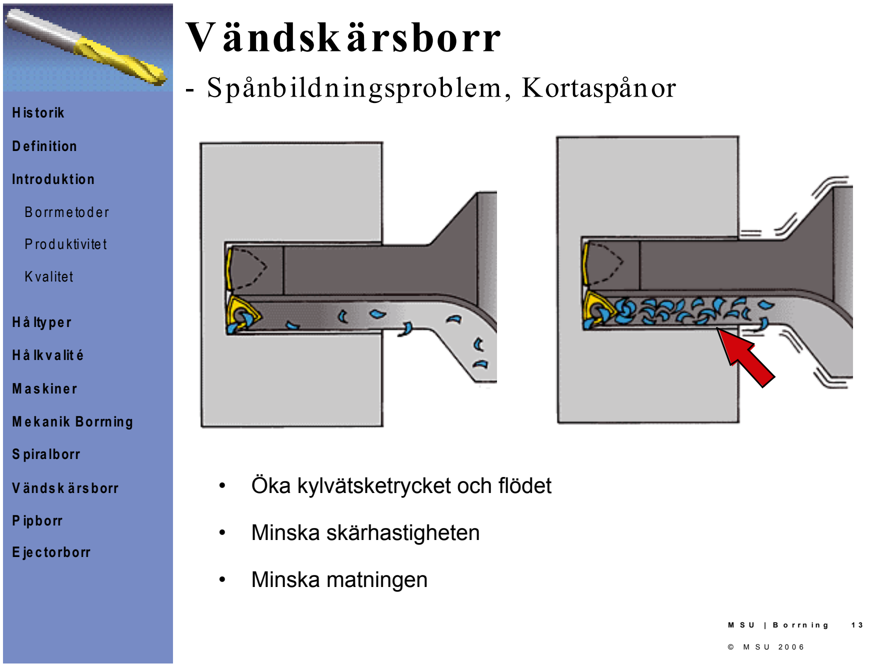


Beräknad temperaturfördelning i ett 2-dimensionellt snitt med värmeflöde till skärets understöd och vidare i verktygshållaren.



Exempel på beräknad temperatur-fördelning med FEM baserad på mätta skärkrafter.

Källa: Sturesson P-O (1998)



Some examples of slides from MSU

Participating parties and Contact person

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Analysis and Optimisation of Cutting Fluids within the Centre for Processing Liquids

This project aims to improve the knowledge regarding correlation between environmentally adapted cutting fluids and their functionality in metal cutting. There is also a combined effort to investigate a number of important issues regarding rules and regulations, working environment and waste management/recycling, equipment, systems design and methodologies.

The participating companies and universities develop new cross-disciplinary co-operation and the competence of the manufacturing companies is strengthened. The PhDs resulting from the project shall have such cross-disciplinary competence that they can support development regarding the implementation of novel cutting fluids and technologies. The intention is also to provide new knowledge that can be implemented in undergraduate and graduate education as well as professional training for engineers and technical staff in companies.

Objective

The manufacturing industry dealing with powertrain and other advanced components manufacturing use processing liquids in many of their machining operations. Correct use and handling of such liquids is mandatory for maintaining productivity and cost control. Demands are set on the cutting fluids and systems design with respect to needs related to working environment, environmental handling and lowered total costs. At the same time, demands on functionality are steadily increased owing to introduction of improved machining concepts and more advanced materials. The problems and issues are complex. The development and application of environmentally adapted cutting fluids requires therefore multi-disciplinary research efforts combined with applied development activities involving both suppliers and users of processing liquids. This project is focused on the analysis and optimisation of future cutting fluids for machining operations. Through the project, the knowledge platform is strengthened among Swedish powertrain manufacturers, other advanced component manufacturers and suppliers of processing liquids and technologies.

The specific goals of the project are:

- to have new understanding regarding the possibilities for application and use of future cutting fluids in machining

- to have new understanding regarding critical factors and parameters regarding the performance of future cutting fluids in machining
- to have a systematic investigation and summarising of aspects of systems design, cleaning, health and environment, equipment

Results and Deliverables

The project started with a pre-study where the issues of all participating companies were addressed on bilateral basis with the academic researchers. This review was done form the perspectives of the users and suppliers of cutting fluids. The results of the pre-study form the basis for the further development of activities. One part of the project organised via KTH deals with the systematic investigation of system design and handling aspects. A web-based protocol has been developed at KTH, but the main effort is through a number of internal seminars. At these seminars, the project participants as well as specially invited external experts address specific issues of common interest. The results of the seminars are summarised and the knowledge gained can be further implemented through documentation and activities within as well as outside the project.

Another part of the project addressed the in-depth studies and investigation of future cutting fluids with respect to their functionality in metal cutting. Focus is on machinability, but other aspects are also considered. One alternative for the evaluation of functionality has been developed. The test shows how cutting fluids can be compared in one single test with varying cutting speeds. It has been proven that the position of build-up-edge formation can be related to the processing parameters, see for example Figure 1.

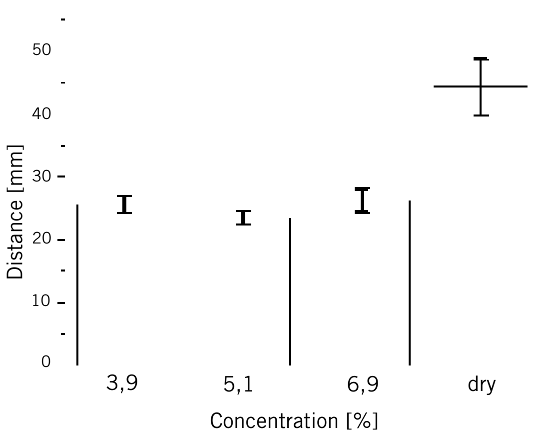

Fig 1. Distance from the periphery to the centre along the surface of a face-turned bar where built-up-edge formation occurs. The comparison is between dry machining and machining with emulsion having different concentrations.

Test material for more advanced experiments has been provided by SKF and Volvo Cars. These kinds of ranking tests include tapping torque tests done by Henkel in co-operation with Chalmers. Chalmers performs drilling test with drill life time predictions and further experiments are done at KTH. In these tests, the conditions of friction, forces and tool wear are investigated. The cutting fluid suppliers provide the cutting fluids used for the experiments. Figure 2 illustrates one example of results gained through these tests. The figure shows the cutting forces (arbitrary units) when drilling in the same test work-piece material with different cutting fluids. From the figure, potential difference in performance can be depicted.

Furthermore, there is a systematic investigation of cutting fluids and systems data done in co-operation between KTH, Chalmers and AB Volvo. KTH and Scania do as well a systematic review of systems design aspects.

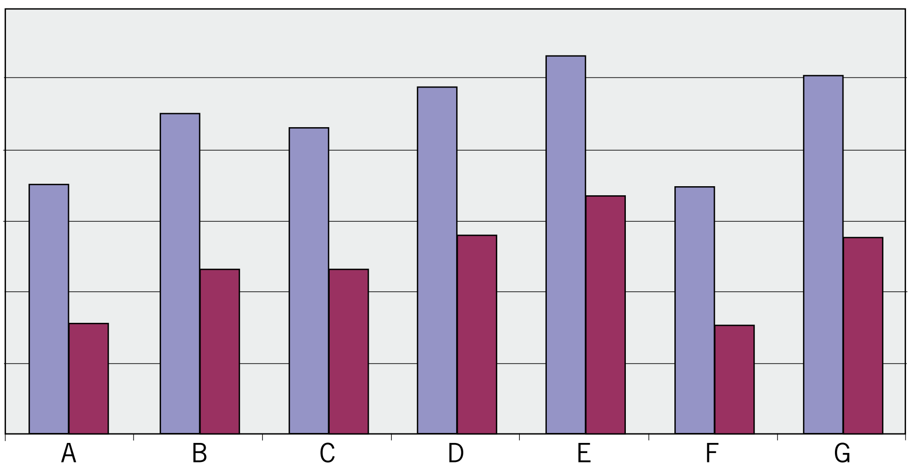

Figure 2. Results from the evaluation of functionality of cutting fluids in machining. The bars show the measured cutting forces (in arbitrary units) when drilling in the same work piece material with the different fluids A-G.

Project Realisation

Project co-ordination and scientific leadership is held by Chalmers through its centre MCR (Metal Cutting Research and Development Centre). Applicant within MERA and industrial co-ordinator is Scania CV AB. Other automotive companies are Volvo Car Corporation and AB Volvo. The other academic partner is DMMS-KTH. Industrial partners outside the MERA-frame funding are AB Sandvik Coromant, SKF Sverige AB, AB Svenska Shell, Henkel Norden AB, AAK/Binol, Nordic Lubricants AB (Castrol), Tool Center Försäljnings AB and Alfa Laval Tumba AB.

The applicant and industrial co-ordinator is Kurt Forsberg, Scania CV AB. The project co-ordinator is Lars Nyborg, Chalmers. The partners involved take part in the steering group for the project. The project involves a full-time PhD student at Chalmers and a PhD student at KTH.

MCR – Metal Cutting Research and Development Centre – is a R&D centre for metal cutting research. MCR has within its area materials- and surface technology competence in applied surface characterisation (surface properties, etc).

Participating scientists are:

Professor Lars Nyborg

Hans-Börje Oskarson

Varun Nayyar, PhD student

Other scientists, technical staff and diploma workers

KTH has formed the centre Design and Management of Machining Systems – DMMS within the School of Industrial Engineering and Management. DMMS is formed through a joint initiative by KTH, Scania and Sandvik Coromant. DMMS deals with manufacturing processes, manufacturing systems, virtual and digital tools for production development, management of production and methodologies.

Participating scientists are:

Professor Mihai Nicolescu

Lorenzo, Daghini, PhD student

Other scientists, technical staff and diploma workers

Department of Chemical and Biological Engineering, Chalmers, have researchers focusing on corrosion, environmental chemistry and industrial recycling. The surface engineering competence within MCR is thereby complemented regarding characterisation and chemical expertise.

Participating scientists and resources:

Professor Lars-Gunnar Johansson, Inorganic environmental chemistry

Other scientists, technical staff, etc, on demand

The project is divided into three stages, valid for both parts given above. The first stage (including month 12) deals with the development of methodologies and knowledge regarding systems aspects and ranking tests. The second stage (including month 24) concerns the application of the methodologies and approaches in the evaluation of future cutting fluids through different machining and other experiments as well as through the synthesis of experiences from the internal seminars regarding systems/equipment/handling issues. The third stage (including month 30), focuses on the implementation of project results and general knowledge through the realisation of education material.

The PhD students will both have taken heir licentiate degree within the project period mentioned. Lorenzo Daghini acquired his licentiate degree during spring 2008 and Varun Nayyar will do the same by the end of 2008.

Project Outcomes

The broad participation of different industrial and university partners strengthens the development in the processing liquid area. At the same time, the manufacturing industry acquires better knowledge regarding important aspects of use of cutting fluids and new knowledge is generated.

The project establishes a co-ordinated research effort that can be strategically linked to other environmentally-driven initiatives within the manufacturing industry. The project also strengthens on long term multi-disciplinary R&D necessary for addressing the complex problems of concern concerning cutting fluids evaluation.

Although the project is on national basis, it has strong international correlation as the suppliers connect globally o their internal and external networks. This means that the project has access to expertise for complicated issues addressed. For example, experts in micro-biology and novel cleaning methods have taken part in internal seminars. The possibilities for adequate implementation of future cutting fluids are thereby enhanced.

The project has provided some spin-off effect already. The ranking studies show consistency between different methods. Working environment aspects have been addressed and discussed. Contacts for potential future co-operation with experts in medical science are taken.

The concept of having a project with a series of internal seminars in parallel to in-depth research activities has proven to be important. In this way, a broader field of knowledge development can be addressed, while keeping focus on R&D activities necessary for progress.

The project is based on the national network of the Processing Fluids Centre. Many of the companies within this network take part in the project, but not all. This network provides excellent possibilities for spreading knowledge gained through the project. The network activities of the Processing Fluids Centre are completely independent from the project in terms of management and funding. It receives no funding from the MERA-programme. The synergies are still evident and the Processing Fluids Centre is the forum for the planning and initiation of continued or complementary R&D activities.

Participating Parties and Contact Persons

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KTH-DMMS

Department of Industrial Production - Professor Mihai Nicolescu

Users and their contact persons

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AB Sandvik Coromant	Göran Mårtensson
Volvo Car Corporation	Håkan Sterner
Volvo Powertrain AB	Petri Anttila
Volvo Technology AB	Martin Kurdve

Suppliers and their contact persons

Nordic Lubricants AB (Castrol)	Mats Johnsson
AB Svenska Shell	Mats Enmark
ToolCenter Försäljnings AB	Hans Landberg
Henkel Norden AB	Kenneth Andersson
Alfa Laval Tumba AB	Staffan Holm
AAK/Binol	Thomas Kandell

KUGG

Gears are and will always be important parts of vehicle transmissions, independent of the type of energy source used. One reason for that is the very good efficiency of gears. By keeping the manufacturing of gear wheels in Sweden, vehicle industry and other high performance machine producers in Sweden are believed to have a good possibility to be successful in an international competition. The general aim of this project is to make sure that advanced manufacturing of gear wheels will stay in Sweden in the future. In order to succeed with that, knowledge of gear manufacturing will be improved both in industry and in academia by the aid of the following three activities: Network activities, Research and development activities and Education activities.

Motivation

The motivation of the KUGG project is to create opportunities for advanced manufacturing of gear wheels in Sweden in the future.

Expected results

Improved productivity and knowledge about gear manufacturing are expected as results both from industrial and academic perspectives. The initially formulated goals were based on what could be predicted at the initiation of the project. They are:

Identify and evaluate the 'bottlenecks' and 'wastes' in the production of the participating companies.

Reduce the amount of standstills of expensive machines with 15 %.

Increase the mean life of expensive cutting tools, as hobbs, by 25 %.

Reduce the number of stops, caused by wrong pre-treatment of tools, by 50 %.

Project realization

Initiations and running of the following three main activities have been judged necessary:

1. Network activities. To make sure that there is a network available for Swedish gear manufacturers, their customers and subcontractors.

2. Research and development activities. To initiate and run research and development activities in production engineering.

3. Education activities. To develop and run courses in gear manufacturing for engineers and technicians in industry, and for research students, with the ambition to work with industry relevant problems.

Results

Network activities

A network for Swedish gear manufacturers, their customers and subcontractors is gradually improved thanks to that the engineers and technicians, who are working with gear production, meet and start to know each other and are involved in different investigations and other activities within the project. Project information is mainly spread by the homepage of the project. All participants in the project can find what is going on in the project. The homepage address is: www.kugg.itm.kth.se

Eleven meetings have been arranged. Foreign speakers have been invited to present interesting and relevant subjects at some of the meetings and the number of participants from the companies has gradually increased.

Research and development activities

The following subprojects are running:

'Surface treatment and surface coatings of tools'. This subproject is lead by PhD Mats Larsson, Primateria AB. PhD students Julia Gerth, Angstrom Laboratory, Uppsala University and Mathias Werner, KTH Industrial Production are working within this subproject.

'Mapping and analysis of gear production'. In this subproject an initial study has been made by Mats Bejhem, KTH Industrial Production together with the PhD student Mathias Werner. The amount of gear production in Sweden was investigated by two students from KTH Industrial Economy in their Master of Science work. Furthermore, four students have studied production at Leax and SwePart Transmission. Three of these students are now employed at the companies.

'Manufacturing of gear wheels'. The following three activities are included:

'Preparation of transmission elements'. This part is treated by the Industrial PhD student Mats Bagge, Scania.

'Functional manufacturing of gear wheels'. This part is treated by the PhD student Ellen Bergseth, KTH Machine Design.

'Gearflank properties and manufacturing'. This part is treated by Sören Sjöberg Industrial PhD student at Volvo Powertrain, Köping.

Education activities

The goal is to develop and give courses in gear manufacturing for engineers and technicians in industry as well as for PhD students. Some general education in gear technology are taught at the Technical Institutes but gear manufacturing is hardly mentioned at all. The education activities has been intensified during the last year. Mart Öhr has been employed at Swerea IVF to work with education in gear technology and manufacturing. A course for people handling the manufacturing machines will be run during 2008 in Köping at their 'Gear Technology Centre'. A doctoral course in Gear Technology with a focus on geometry has been held at KTH.

Effects so far

A homepage was initiated at the very beginning of the project in order to spread relevant information to the participating companies. The address to the homepage is: www.kugg.itm.kth.se

Eleven gear meetings have been arranged. The Network meetings have been held at:

Scania, Södertälje
GM Powertrain, Gothenburg
Erasteel Kloster, Söderfors
Volvo Powertrain and Leax, Köping
KTH, Stockholm
SwePart Transmission, Liatorp
Scania, Södertälje
Ångströmlaboratoriet, Uppsala
Volvo CE, Eskilstuna
Albin Components, Kristinehamn
Gear Technology Centre, Köping

The PhD students Julia Gerth, Mathias Werner and Ellen Bergseth have been practising at Volvo Powertrain and Scania in order to get a better connection and better understanding for the industry problems. Julia and Mathias have made some cutting experiments together and they have also investigated wear of some hobbs, which have been used by some of the participating companies.

The industrial relevance of the research is supported by the involvement of the two Industrial PhD students in the project.

Made Master Theses work have lead to that some of the students are now employed at the companies where the studies were made.

During 2008 education for people, who handle the gear manufacturing machines will be performed at the Gear Technology Centre in Köping. Preparation of the education rooms and machines are made and an initial test course is performed. A PhD course in Gear Technology with a focus on gear geometry was held at KTH.

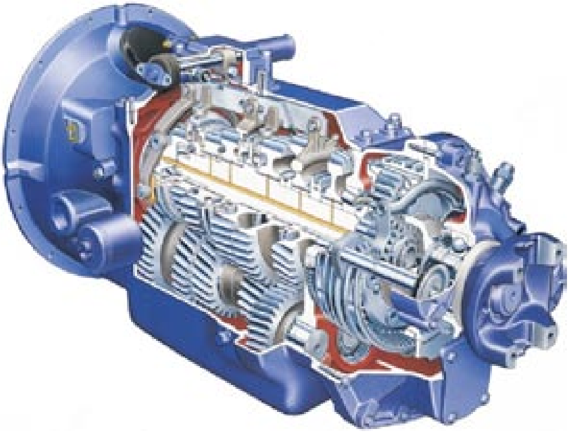
Participating parties and contact persons

The following parties participate in the KUGG project

Company	**Contact person**
Scania CV AB	Ulf Bjarre
Volvo Powertrain Sweden AB	Shiva Käck
Volvo Construction Equipment AB	Mats Andersson
GM Powertrain Sweden AB	Ulf Svensson
Albin Components AB	Robert Johansson
SwePart Transmission AB	Hans Hansson
Leax AB	Åke Zetterberg
SVA AB	Jan Svensson
Erasteel Kloster AB	Johan Ahlberg
Meritor HVS AB	Ulrica Hellsten
Primateria AB	Mats Larsson
Swerea IVF	Mart Öhr
Akademia	
KTH Industriell Teknik och Management	Sören Andersson
Ångströmlaboratoriet, Uppsala Universitet	Sture Hogmark
Other participating company	
Getrag	Joakim Johansson
Oerlikon Balzers	Susanna Weinberger
Ionbond	Greger Håkansson
Höganäs AB	Anders Flodin

Contact persons for the project

Chairman for the project: Ulf Bjarre, Scania AB
Projectleader: Sören Andersson, KTH Maskinkonstruktion
Contact person regarding education: Mart Öhr, Swerea IVF AB
Contact person regarding surface coatings: Mats Larsson, Primateria AB



Gears

A coated hobb for gear cutting

Network meeting in August 2006

MERA conference 2008

Forming and joining of sheet metal

Modelling and simulation of simultaneous forming and quenching of Boron steel

The aim with the project is further development of material- and process simulations to be able with good accuracy predict the final geometry of the product, material composition and material properties in the development of press hardened components in ultra high strengths Boron steel. The main focus in the project is to explore the heat transfer between the hot blank and cold tool, which occur during simultaneous forming and quenching. An experimental setup is developed to investigate different process conditions effect on the heat transfer. Results from experiments together with inverse modelling are used to develop a model of the heat transfer coefficient that can be used in thermo mechanical forming simulations.

Objective

Modern process- and product development uses more and more numerical simulations to predict the behaviour and to optimize the performance of the process/product. This is also true for the press hardening process/products where the simulation tools continuously are improved, especially forming simulations. But one area where few works are published is the transfer of heat between the hot blank and cold tool, which this project is focused on. The transfer of heat is a key process in the press hardening process which affects the mechanical properties during and after forming, microstructure and the final geometry. The objective with this work is to develop a model of the heat transfer coefficient during different process condition, which can be used in thermo mechanical forming simulations. The accuracy of the forming simulations will be improved regarding mechanical and material properties and final geometry and also the successive crash simulations.

Results

A new experimental setup is developed where different process conditions effect on the heat transfer coefficient can be evaluated. For example blank material, contact pressure and surface texture of tool. The equipment is relatively robust and the repeatability is good. The results from the experiments are used with an inverse numerical modelling technique to predict the interfacial heat transfer coefficient (IHTC) in press hardening. Important conclusions regarding pressure and material dependency are confirmed. The results are implemented in a subroutine in the nonlinear FE-program LS-Dyna and are used in thermo mechanical coupled forming simulations at Gestamp HardTech.

Project realization

The experimental equipment developed within this project consists briefly of a circle shaped blank that is pressed between two tools, see figure 1. During quenching of the blank the temperature response in the tools is recorded. The temperature response in the tools is used in the inverse simulations to predict the heat transfer coefficient. In figure 2 the normalized heat transfer coefficient is presented at different contact pressures and blank materials.

Figure 1. Experimental setup

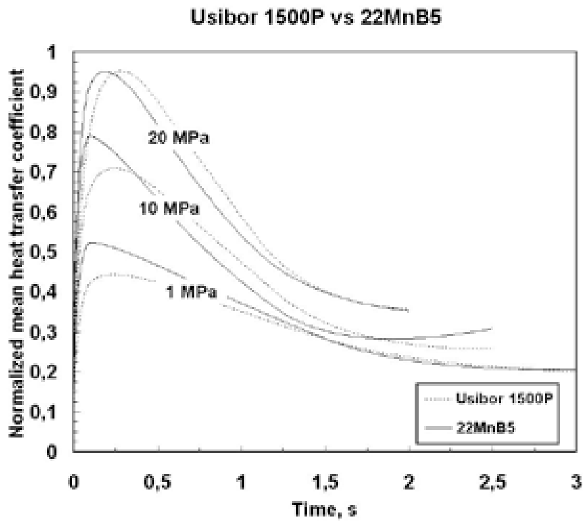


Figure 2. Normalized heat transfer coefficient at different contact pressures and blank materials. (22MnB5=uncoated boron steel, Usibor 1500P=AlSi coated boron steel)

Project outcomes

The knowledge and the effect of different process parameters on the heat transfer in the press hardening process has increased. The accuracy in the thermo mechanical coupled forming simulations is also improved when these new results are implemented at Gestamp HardTech.

Participating parties and Contact person

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Cost and Lead Time Saving Die Manufacture

The higher product requirements, reduced weight, increased safety and lower emissions, have entailed that a larger number of car (or cab) body parts must be made in advanced high strength steels. This has led to a significantly larger abrasive and adhesive tool wear. In the same time the product life cycle and serial length are decreasing witch means that less products have to carry the tool and die manufacturing cost. However, by this project a package of solutions can be presented in order to meet the new industrial challenges. This is accomplished with new strategies and guidelines for selection of tool materials, hardening methods, surface topographies, coatings and surface treatments. Calculations show that cost and lead time can be reduced up to 60 % and 30 % respectively. The reduction is depending on the forming complexity of the part.

Objective

Tools and dies constitute a major part of the global product creation. The global turnover of tools was 580 000 million USD year 2000. The automotive industry stands for a large part of this turnover. The cost of stamping dies, forming/blanking/cutting/trimming dies, for a new car model totals 100-140 million USD. In other words, stamping dies is a major part of the investments required, as a new car or cab model is developed.

The product life cycle is decreasing. For passenger cars, the life cycle has decreased from 7 to 5 years. An increasing number of models are introduced on the market faster and faster. Time-to-market is reduced and the demands are high on the automotive industry capability to develop new products in a shorter time. Tool and die creation is a major part of the product creation.

The purpose with this project is to establish cost and lead time reducing guidelines/tool concepts for forming and trimming dies.

Project realization

Three different working steps have been performed to improve existing die standards in this project. The purpose of mode of procedure is to quickly and cost-effectively limit the number of possible options. The steps are laboratory testing, semi-industrial testing and industrial verification, displayed in Figure 1.

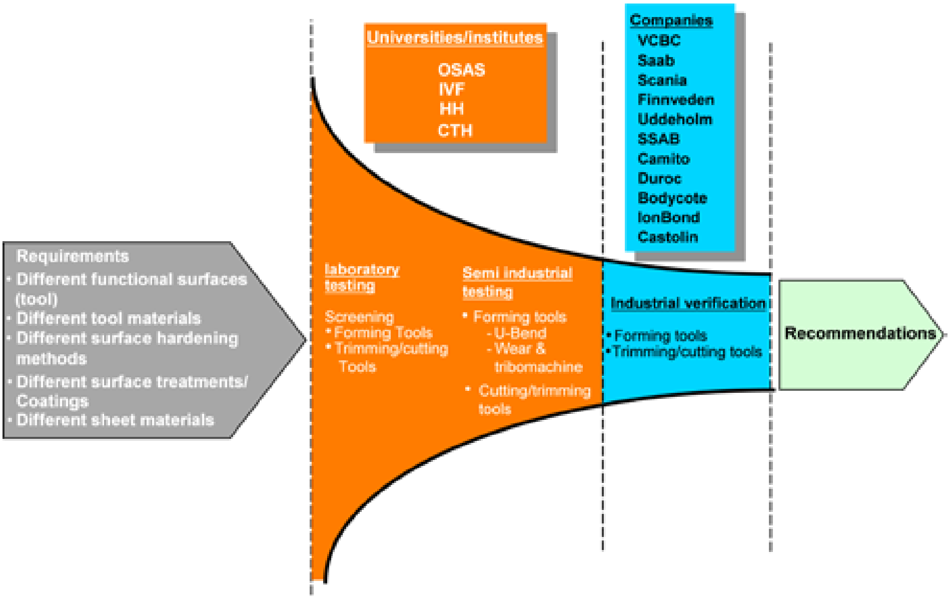


Figure 1. The selected Mode of procedure.

Based on requirements, different functional surfaces, tool materials, surface hardening methods and surface treatments/coatings, laboratory screening tests are performed to find suitable working solutions for forming and trimming tools.

In the semiindustrial testing, the test method is more complicated but also closer to reality. In this stage, simulation has been performed which gives process parameters similar to real production. The tests are performed in OSAS U-bend and cutting test.

The semi-industrial tests reduce the number of industrial verifications. This is necessary since the industrial verification is costly and time consuming. The result from the industrial verification process are recommendations/guidelines for functional surfaces, tool materials, hardening methods, surface treatments/coatings, and welding of forming and cutting tools for manufacturing of parts in different sheet metal qualities (strength, thickness, coated or uncoated) and total production volumes.

Results and deliverables

Functional tribological working surfaces

In order to create functional tribological working surfaces for the "dry press shop", the tribological conditions have been investigated in laboratory studies. The results showed that the hydrodynamic effects were significant even when the lubricant was applied in very low quantities (0,1-1,0 g/m^2). Thereby one conclusion from this study is that the polishing direction should be applied perpendicular to the sliding direction in order to reduce friction and wear, see Figure 2.

Today about 80 % of the sheet material in a modern car consists of MS and HSS-sheet. In most applications nodular ductile iron is used as die material to form the parts. It is therefore important to clarify how a nodular ductile iron should be designed to achieve a functional tribological working surface. Tests results show that resistance to galling was significantly improved when the nodules are small and in high numbers, see Figure 3.

Semi industrial tests and industrial verification

To achieve the project goals, a large number of different qualities of tool materials with appropriate heat treatments and surface coatings were tested against different sheet material qualities (MS to UHSS). The tests were analyzed and evaluated with respect to, abrasive and adhesive wear, part quality, wear on the tool surface, cutting edge radius, area wear in cutting edge, cutting clearance and burr height.

The semi-industrial results showed that it is possible to reduce costs and lead time for tool and die manufacturing by increasing the use of cast materials (steel and iron) and surface hardening (laser hardening). Laser hardening provides sufficient support for forming and trimming tools, it is also enough to support a PVD layer, independent if the tool material is cast or wrought.

Tool concepts with successful results in the semi industrial tests are selected for industrial verification. Figure 4 and 5 show examples of industrial verification of forming tools where the tool concept is cast Carmo (Wr.-No. 1.2333) with laser hardening and low temperature PVD. Sheet materials are 2660, t=3.0mm, Rp_{02}≈490MPa (see Figure 4), and Dogal 600 DP, t=1.7mm, $Rp_{02} \approx$ 300MPa (see Figure 5). Figure 6 show an example of a cutting tool where the concept is laser hardened nodular ductile iron (EN-JS 2070), sheet material is DC04, t=1.4mm, Rm≈300MPa.

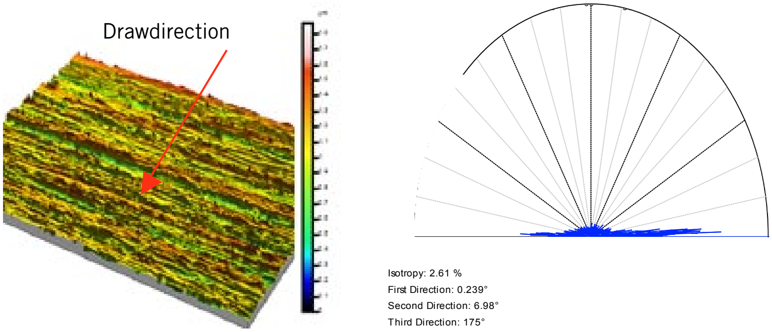
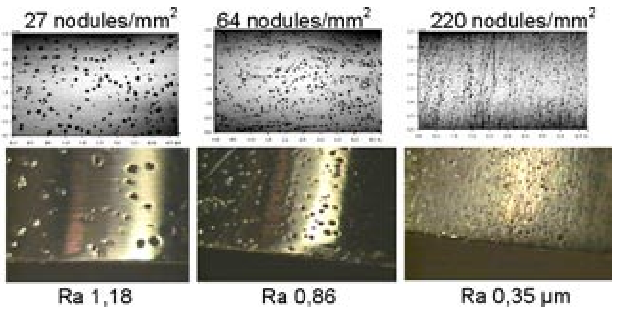


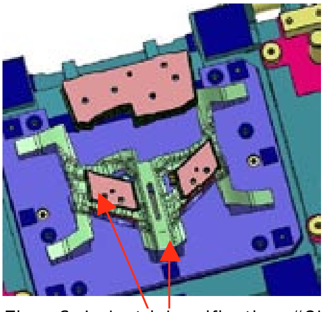
Figure 2. The polishing direction should be applied perpendicular to the draw direction in order to reduce friction and wear.



Figur 3. Pictures show different qualities of nodular ductile iron that have been tested

Figure 4 Industrial verification “Towing eye” (Finnveden)

Figur 5. Industrial verification ”Crossmember Firewall” (Volvo)



Figur 6. Industrial verification, “Closer Brace” (Volvo)

Investigation of the cutting edge geometry

The geometry of the cutting edge has been investigated in following two steps:

- How the initial cutting edge radius and the angle of the upper tool affects wear when cutting in the normal direction of the sheet material.
- How to improve part quality and reduce tool wear when cutting in the “non” normal direction of the sheet material.

Results from the semiindustrial tests could not show that an increase of the cutting edge radius from 20μm to 80μm decreased the wear. However, industrial experience indicates that a larger radius can reduce the risk of “chipping” on the cutting edge during the tryout. An angle of 93 degrees compared to 90 degrees on the upper trim steel resulted in a reduction of the cutting work by a few percent. Performed FE simulations correlate well to these results.

The evaluation of cutting in the “non” normal direction of the sheet material shows that an alternative design of the lower cutting edge improves the part quality and reduces the side forces compared to regular geometry. Results of the FE simulation of these two cases are shown in Figure 7, where the lower edge of the part is less sharp, this is verified in semiindustrial tests. This result indicates the possibility to cost reduction by avoiding moving shuttles.

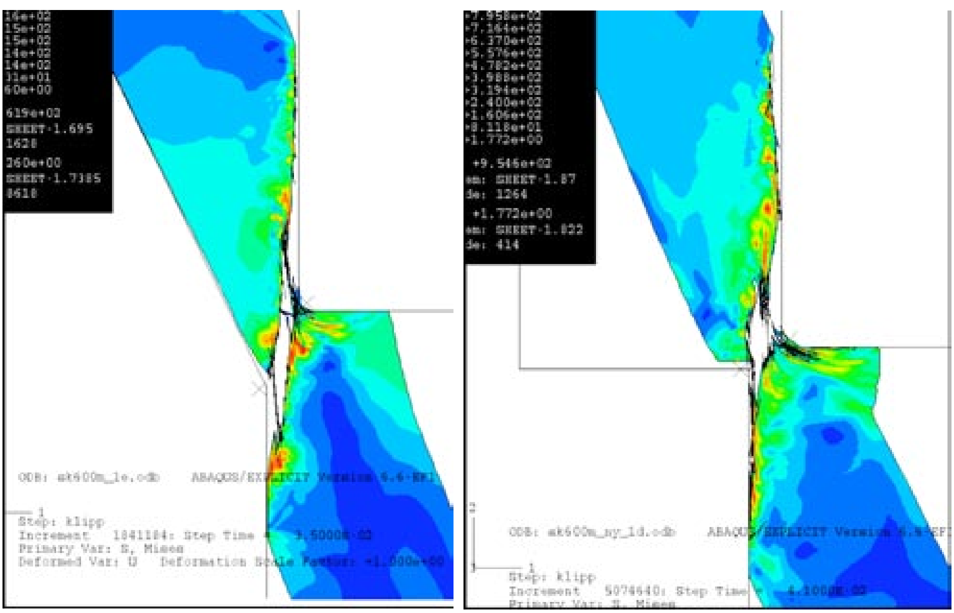


Figure 7. Simulated result of cutting Docol 600DP t=1,2mm, cut at an angle of 60°. Left: Traditional design. Right: Cutting edge with a 1,5mm “shelf”.

Welding

Welding is an important part of die manufacturing and maintenance. Investigations have been performed with the purpose to increase the knowledge regarding welding methods, consumables and electrodes. Results indicate that, among other things, the sheet material quality has to be considered, not only the weldability of the substrate material.

Project outcomes

Industrial verifications with approved performance, result in concept recommendations and guidelines. Table 1 shows an example of recommendation for forming of EHSS sheet material up to 150 000 strokes. Table 2 shows an example of recommendation for cutting of HSS sheet material up to 150 000 strokes.

Table 1. Tool concept for forming of EHSS sheet material, up to 150 000 strokes.

		Docol 600 DP (EHSS), 150 000 strokes			
		Sheet thickness, t<1.2		Sheet thickness, t>1.2 mm	
		Coated	Uncoated	Coated	Uncoated
Present Guidelines	Punch	GGG70L[1]	GGG70L[1]	GGG70L[1]	GGG70L[1]
	Lower Die	GG25	GG25	GG25	GG25
	Inserts	Calmax[2]+Nitr Sleipner[2]	Calmax[2]+Nitr+PVD[5] Sleipner[2]+PVD[5]	Calmax[2]+Nitr Sleipner[2]+Nitr	Calmax[2]+Nitr+PVD[5] Sleipner[2]+PVD
	Blank holder	GGG70L	GGG70L[3] Calmax[4]+Nitr+PVD[5] Sleipner[4] + PVD[5]	GGG70L[3] Calmax[4]+Nitr Sleipner[4]+PVD[5]	GGG70L[3] Calmax[4]+Nitr+PVD[5] Sleipner[4]+PVD[5]
New Guidelines	Punch	GGG70	GGG70[6]	GGG70	GGG70[6]
	Lower Die	GGG70L[7]	GG25	GGG70L[7]	GG25
	Inserts	-	Calmax[7]+PVD[8]	-	Calmax[7]+PVD[8]
	Blank holder	GGG70L[7]	GGG70L[7]	GGG70L[7]	GGG70L[7]
Circa saving	Lead time	-60%	-45%	-60%	-45%
	Cost	-30%	-20%	-30%	-20%
Comments	[1]Steel inserts at expected wear areas. [2]All insert through hardened. [3]Without drawbeads. [4]With drawbeads.		[5]PVD = CrN or TiAlN. [6]If there is material transport change to GGG70L [7] Laser Surface hardening [8] Low temperature PVD (TiAlN)		

Table 2. Tool concept for cutting HSS sheet material up to 150 000 strokes.

	MS+HSS, 150 000 strokes			
	Previous guidelines		New guidelines	
	t≤1,2mm	t≤2mm	t≤1,2mm	t≤2mm
Upper Die	Fermo	Fermo	GGG70	GGG70L
Lower Die	Fermo	Fermo	GGG70	GGG70L
Savings	Calculations are ongoing			
Comments	Induktionhardening		Laserhardening	

Knowledge generation

A database platform for choice of tool concepts (forming and trimming) is on going. The purpose if this database is to serve as a guide when selecting tool material and manufacturing methods when designing forming and trimming tools with different volume scenarios and different sheet material qualities. See: http://hefaistos.ivf.se/totalansvar/utveckling/

Scientific publications

- "Die materials, hardening methods and surface coatings for forming of high, extra high & ultra high strength steel sheets (HSS/EHSS/UHSS)", IDDRG 2006, Porto (Portugal)
- "On laser hardening of trimming tools & dies", IDDRG 2006, Porto (Portugal)
- "Measuring strategies for smooth tool steel surfaces", 2008, Chemnitz (Germany)
- "Guidelines for die materials, hardening methods and surface coatings for forming of high, extra high & ultra high strength steel sheets HSS/EHSS/UHSS)", IDDRG 2008, Olofström (Sweden)
- "Improved nodular iron for forming dies to obtain functional die surfaces, IDDRG 2008, Olofström (Sweden)
- "A friction model of sheet metal forming evaluated with results from a bending-under-tension test", Nordtribs 2008 Tampere (Finland)
- "Cutting AHSS materals in the non normal direction of the sheet material", Swedish Production Symposium 2008, Stockholm (Sweden)

Participating parties and Contact persons

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FE-simulation of Sheet Metal Forming

A project where Volvo Cars, SAAB Automobile, Scania, Finnveden Metal Structures, SSAB, Chalmers University of Technology, Linköpings University, School of Engineering at Jönköping University, IVF Industrial Research and Development Corporation and Industrial Development Centre in Olofström work together. The aim with the project is to further strengthen Sweden's strong position within this field of research. This will be done by additional improvements of the accuracy of today's sheet metal forming simulations as well as development of new simulation applications for design and manufacturing of stamping dies for sheet metal components. The total budget for the project is 34.5 MSEK, which 15.99 MSEK is provided by VINNOVA and the remaining part is funding from the industrial partners.

Objective

The aim with the project is the further develop the methods for FE-simulations of sheet metal forming. This will give the industry additional reductions of the lead time for design and manufacturing of stamping dies together with increased robustness of manufacturing process for sheet metal components.

The vision is that FE-simulations of sheet metal forming after the completion of this project will be able to:

- Correctly predict more result parameters than today, e.g. the geometry of the component after stamping, the influence on the results from scatter of the material properties and forming process parameters, etc. This should then be done for all material grades used today in the industry as well as new advanced multi phase materials like TWIP and TRIP.
- Increase the accuracy and complexity of the FE-simulations without no major increase of simulation lead time.
- The results after sheet metal forming simulations should be exported to other CAE groups and used as input in their analyses.
- Optimize the stamping die structure by also take the casting of the die into consideration. The accuracy of sheet metal forming simulations will then be increased by including the die stiffness in the analysis. All these results and experiences will also be used for improving today's design rules for stamping die design.

Results and deliverables

Results from the project has up to 2008-09-30 been published and presented in one PhD-thesis and twenty five papers in different journal and conferences.

In Sub-project 1, the PhD-student has, in corporation with IDC in Olofström, determined all material parameters for simulation for the sheet materials used in his work (a mild steel, an IF-stål and two different DP600 grades). He is also leading a master thesis work on the influence of plastic deformation on the Young´s modulus. He has also developed a new, effiecnt method for the determination of hardening parameters for simulation with experimental results from a three-point bending test.

In Sub-project 2 the work during the autum of 2007 has been concentrated on studies of forming parts with FLEX-Rail die from the Simuformproject. A smaller study on the influence of the yield locus on the forming and sprinback results was a part of this work. After that, the PhD student have planned new tests of DP600 with non-proportional strain path. The idea is to pre-strain a large sample uniformly and then cut out smaller samples for tenslie tests. These new material data should then be used for further simulations of forming of panels in the FLEX-Rail die.

In Sub-projekt 3 are the studies of the stress lattice finished and the results sumarized in a journal paper. Also the simulation study of residual stress after casting in a standard and topology optimized stamping die are concluded. The simulations indicates residual stresses as lagre as 200 MPa in the major strain direction. These stress levels can not be neglected in design and quenching of stamping dies, see Figure 1.

The work with method development for stocastic simulation and definition of material and process variation continous in Sub-projet 4. Determination of the scatter of mechanical properties of a DP600 grade has been performed at IDC in Olofström. An analytic study of the influence of different material parameters on the yield locus shape has been performed. The study focused on the YLD2000 material model but can easily be extended to other material models. A pilot project on stochastic sheet metal forming simulations have been done in corporation with SCANIAs cab factory in Oskarshamn. The sub-project and the results has been presented at a visit at Ohio State University, the Department of Design and Manufacturing.

In Sub-project 5 has a project on failure prection i sheet mateterials with fracture mechanics been started. The academic partner in this case is Department of Solid Mechanics at The Royal Institute of Technology, Stockholm.

The industrial studies has been focused on two major subjects, prediction of localisation and the determination of material properties for sheet metal forming simulations. An experimental die equiped with cameras for on-line strain measurments are displayed in

Figure 2. This die is used at IDC in Olofström for determination of material parameters for sheet metal forming simulations. Results from different experiments in this die in combination with new, more advanced material models, have already shown major inprovements of the sheet metal forming simulation accuracy, see Figure 3.

Project realization

The project is realized by:

- Three PhD projects
  - Sub-project 1: Springback predictions, Chalmers University of Technology
  - Sub-project 2: Material models for sheet metal forming simulations, Linköpings University
  - Sub-project 3: Die structure optimization, School of Engineering at Jönköping University.
- A research project at IVF about stochastic simulations and process robustness prediction (Sub-project 4)
- A few shorter studies (Sub-project 5).
- Joint studies at the industrial partners.

Project outcomes

A very important industrial result is to reduce the cost for design and manufacturing of stamping dies. Therefore this project has common interests with the MERA-project ”Cost and lead time saving die manufacture”. For a complete view of the situation we advice to also study this project expected results.

A conservative cost estimate reveals that small savings on each manufactured die will generate large cost reductions due to the large number of dies used. To estimate the cost reductions the following analysis has been made. The try-out of dies are done in a number of loops, where each loop is the time spent and work needed from that a problem is observed, e.g. factures or large springback, until the die is tested again after modifications. This is an iterative process which has a negative effect on the lead time and is also costly. The aim is therefore to reduce the number of try-out loops and one goal of this project is to remove one try-out loop of each die set (all dies need for production of a component). Assuming that the average cost for each loop is 0.2 MSEK, the total savings at the industrial partners over four years will be 440 MSEK which equals that a krona spent by the industry will pay back 23.75 SEK in cost reductions.

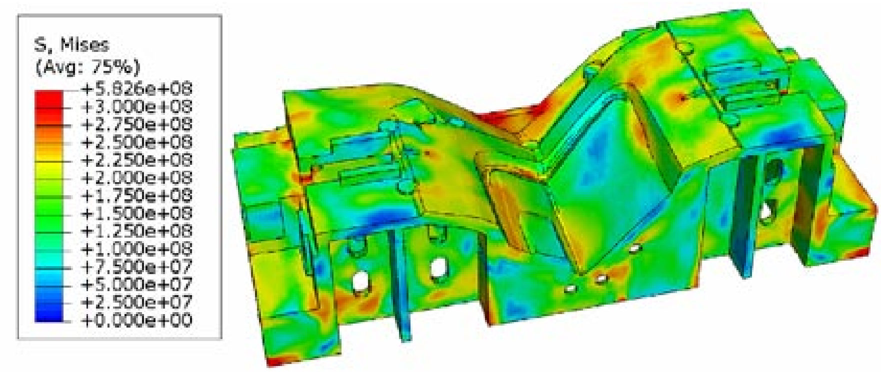

Figure 1. Residual stresses in a stamping die after casting.

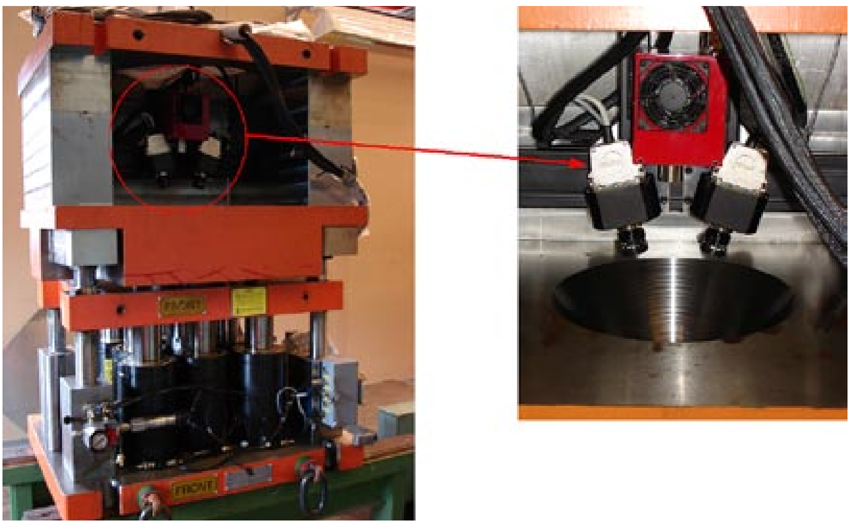

Figure 2. Stamping die for determination of material data for sheet metal forming simulations. Each experiment is filmed with the two cameras mounted in the die.

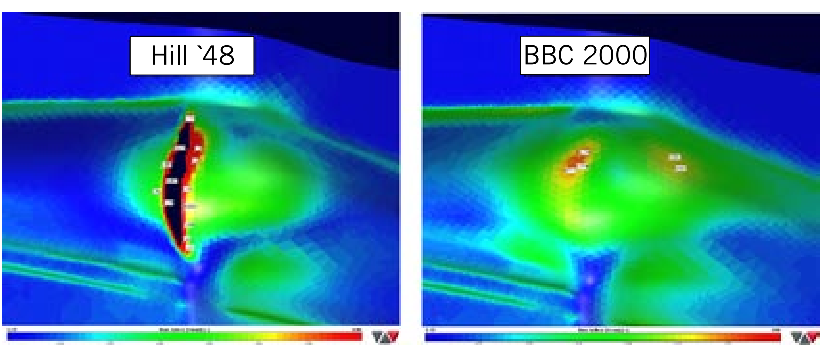

Figure 3. Simulation results of the forming of a component using two different material models. The results using BBC2000 material model (right) show very good agreement with experimental results while the results using Hill ´48 material model (left) deviates substansially from experimental results.

On top of these large savings are other industrial gains that are hard to perform cost estimates on:

- Reduced lead time for design and manufacturing of stamping dies for new vehicles.
- Increased knowledge and understanding of sheet metal forming.
- Less production problems
- Increased quality of the vehicles
- Increased safety of the vehicles
- Reduced weight of the vehicles.

The academic goals are that the three PhD-students will receive their Licentiate of Engineering degrees during 2009. The results from their research as well as from other studies performed in the project should be reported in papers presented at international conferences and journals.

Participating parties and Contact person

Industrial representatives	Mats Sigvant	Volvo Cars Body Components
	Mats Larsson	SAAB Automobile AB
	Lars Gunnarsson	Scania CV
	Jan Rosberg	Scania CV
	Peter Alm	Finnveden Metal Structures
	Lars Troive	SSAB Tunnplåt AB
Sub project 1	Kjell Mattiasson	Research leader
Chalmers University of Technology	Per-Anders Eggertsen	PhD -student
Sub project 2	Larsgunnar Nilsson	Research leader
Linköpings University	Rikard Larsson	PhD -student
Sub project 3	Niclas Strömberg	Research leader
School of Engineering at Jönköping University	Magnus Hofwing	PhD -student
Sub project 4 IVF	Elisabeth Sagström	Research leader
Sub project 5 IDC in Olofström	Per Thilderkvist	Research leader
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A new production technology for hemming – PROFAL

The overall objective of this project was to develop a new unique and innovative manufacturing method for hemming of sheet metal components. The project was object driven: product requirement direct the development of the manufacturing production process. There are several mechanical methods to hem sheet metal parts together. Hemming is the process whereby the edge of the sheet is folded to 180° to join to an inner part. Often glue or sealants are in the hem to create a hermetic joint or greater structural robustness. Examples of automotive components that are joined by hemming are hoods, doors, sunroofs and fuel-filler doors. The disadvantages with conventional mechanical hemming are that it is expensive production equipment, splitting, wrinkles, springback, warping, surface defects and the expensive glue in the hem. In addition, there is a very long lead-time in developing the heavy traditional hemming tools. This project have created a new unique, innovative production method were an electromagnetic pulse process has created an electromagnetic pressure that was used to achieve the hemming process.

Objective

The purpose of this research project was to develop a cost effective, new and innovative manufacturing method for hemming for automotive components. The suggested manufacturing process includes an electromagnetic system to produce a pressure that can create a structural crimp (which can avoid the need for adhesives), or possibly even a solid-state impact weld. A typical electromagnetic manufacturing system includes a power supply, which contains a bank of capacitors, a high-speed switching system and a coil. For electromagnetic hemming the coil is positioned close to the flange that should be hemmed. The capacitor bank is recharged and the switch opens up the current to flow through the coil. When this happens, a high-density magnetic flux is created around the coil, and as a result an eddy current is created in the flange of the sheet metal part. The eddy currents oppose the magnetic field in the coil and a repulsive force is created. This force can drive the flange against the inner panel at an extremely high rate of speed and at impact a metallic hermetic tight joint may be produced. A schematic description of an electromagnetic manufacturing system is shown in figure 1.

Results and deliverables

In the early stage of the proposal the goal and achievement with this project was expected to be:

- A new innovative and robust production process for hemming
- Reduced initial investment and reduced cost to operate
- Reduced hemming scrap rates
- A low-cost method in sense of investment and production
- Decrease lead-time for hemming processes
- Elimination of spot-welding and gluing processes
- The possibility to create superior metallic joint between steel and aluminium
- Improved joint and geometrical quality

To develop the electromagnetic pulse hemming process according to the expectations above then three demonstrators were designed. The results from the experimental tests can be concluded as:

- A hemming process in one step is possible to achieve and works better for al alloys then for carbon steel due to aluminium's higher conductivity
- The process itself its extremely robust due to that same energy level is charged every time.
- A metallic joint is not possible to achieve during an electromagnetic pulse hemming process that is made in one step and this makes it difficult to remove the adhesion and spotweld process. One possibility is to make a prehem either with a roller hem and subsequently use a electromagnetic pulse to achieve a cold weld in the hem joint. This has not been tested in this project.
- The flange height should preferably be lower then 7mm to optimise the electromagnetic pulse hem process. This increases also the quality aspect of the final hem.
- The coil position should be positioned high up on the flange.
- The process time for hemming of closure will not exceed 20 sec independently of the size. The charging time of the capacitors controls the process time.
- The required energy level depends on the coil design and sheet materials conductivity and not on the coil length ie the closure geometry.
- With different type of coils can the same electromagnetic pulse system be used to first cut the blanks, flange the outer part and finally making the hem. This has been shown in the project.

- The cost compared to roller hemming is not lower for traditionally hemming. The cost become lower if a coldweld could be achieved due to the reduction of adhesion and sealing systems.

Project realization

The first step was to analyse the hemming operations and hemmed products that are used today at Saab Automobile and Volvo Truck. After that, demonstrators were developed to incorporate standards from both Saab and Volvo Truck in sense of radius, flange heights and clearance.

To analyse the electromagnetic pulse hemming process, three demonstrators were developed in this project:

1. A bean shaped part with different flange heights and radius, see figure 2
2. A straight part, see figure 3.
3. A part with the shape of a fuel filler door, see figure 4.

All experiments were made at The Department of Materials Science and Engineering, Ohio State University. The systems that were used for our experiments were both Magnafom with either 16kJ or 48kJ capacitor bank. The sheet materials in this project were aluminium alloys AA6016-T4 and AA5182 as well as the carbon grade 1157-42 (Volvo Truck designation) with a thickness variation between 0.9 to 1.2mm. By design of experiments the flange height, radius and coil position vs. flange was varied to analyse these parameters influence for the electromagnetic pulse process. Some examples are shown in figure 5 and some of the final parts are shown in figure 6.

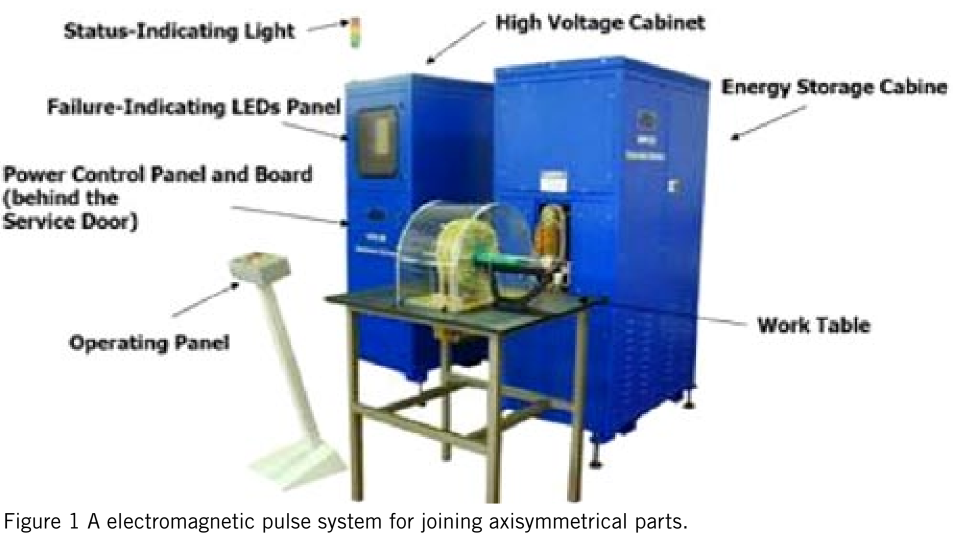


Figure 1 A electromagnetic pulse system for joining axisymmetrical parts.

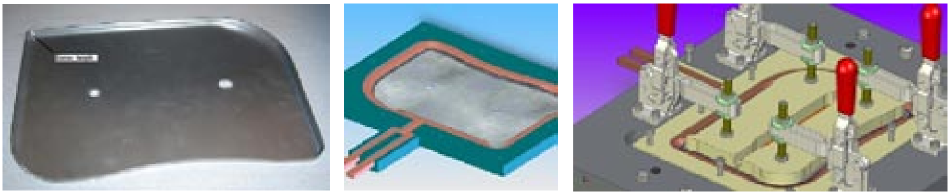


Figure 2 show demonstrator 1.

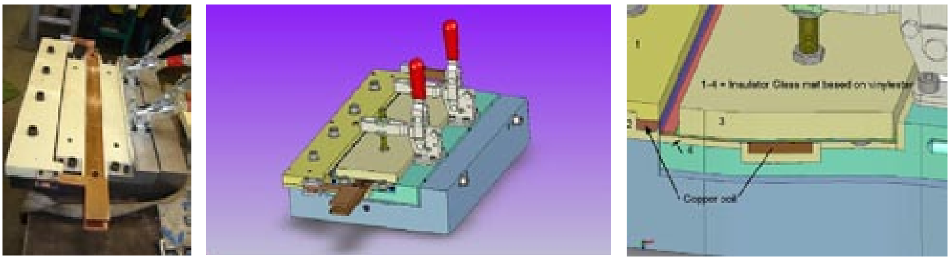


Figure 3 show demonstrator 2.

a) b) c)

Figure 4 show demonstrator 3 which were manufactured in three stages with the same electromagnetic pulse system. Stage 1 a) is after the blanking operation, b) show the flanged part and finally c) the hemmed part.

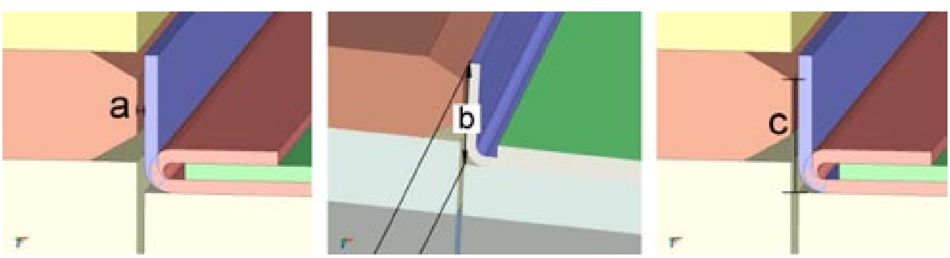


Figure 5 Some of the parameters that were varied in this project.

Figure 6 shows on some of the final hemmed parts made by electromagnetic pulse.

The positions at the hem for the analyse is described in figure 7 and the grading and measured geometries is described in figure 8.

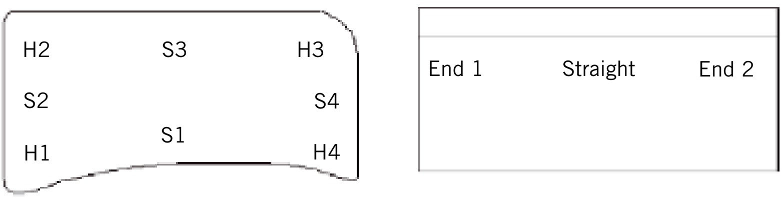
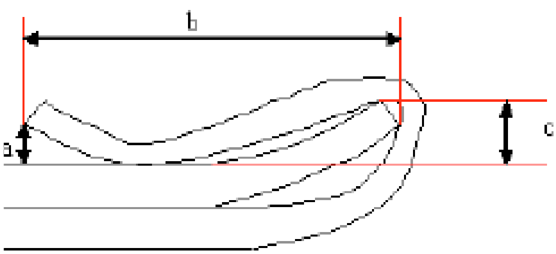


Figure 7 Geometries and explanation for the different test specimens



Grade	Grading	Comments
1	Bad	Tearing, not folded, deformation
2	Not approved	Not folded, deformation
3	Approved	Mechanically bonded, som deformation
4	Good	Mechanically bonded, partially welded, small deformation
5	Exellent	Welded with small deformation

Figure 8 Explanation of grading

After the analyse of all specimens the maximum grade were 3 for demonstrator 1 and 3. With some minor optimisation and more experiments we believe that we can reach grade 4 due to the fact that we have a minor tendency to a weld for demonstrator 1.

Project outcomes

A new unique process for electromagnetic pulse hemming has been developed. This method has the best potential for long series due to high initial investment cost and that the process is exceptionally robust. One way to reduce the cost could be to hem several closures at the same time due to the fact that a longer coil hardly increases the required energy level.

Participating parties and Contact person

Participants:

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SAAB Automobile	Sven-Ove Olsson	Industrial partner
Svensk Verktygsteknik	Roger Andersson	R&D partner
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Metal sheet roller hemming in high production volumes

This project aims to improve the robot roller hemming concept to be capable not just for spare parts, low volume and prototype production but also for regular high volume manufacturing.

Objective

Metal sheet hemming is traditionally performed using a press or a hemming machine with moveable beams. Roller hemming is an alternative method, where the parts are placed in a dedicated bed and the hemming operation is performed in progressive steps by a roller operated by a robot, see figure 1.

Roller hemming compared to traditional hemming means lower investment and increased flexibility, but the method has been limited to low volume applications and products with a low level of complexity.

The objective of the project has been to expand the field of application into higher volumes and higher levels of product complexity.

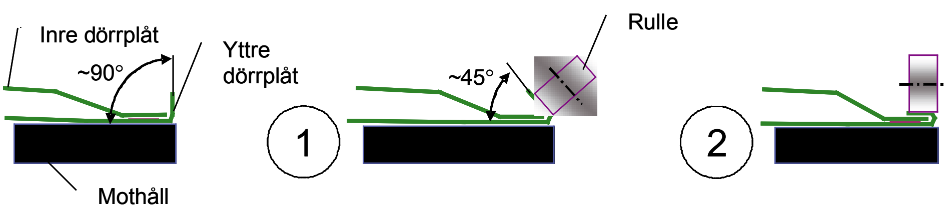

Figure 1. Roller hemming principle

Results and deliverables

The project has developed methods for off line programming resulting in processes with cycle times lower than what has been possible up to now. A specification of product requirements has been developed. Furthermore, a pre-study of a virtual method to predict the hemming result has been made. The outcome of this pre study is a new project within the MERA-program focusing on the virtual methods.

The project results has been demonstrated in the test and verification equipment that was built within the project, see figure 2. A patent of a roller head enabling simultaneous two step hemming is another result from the project.

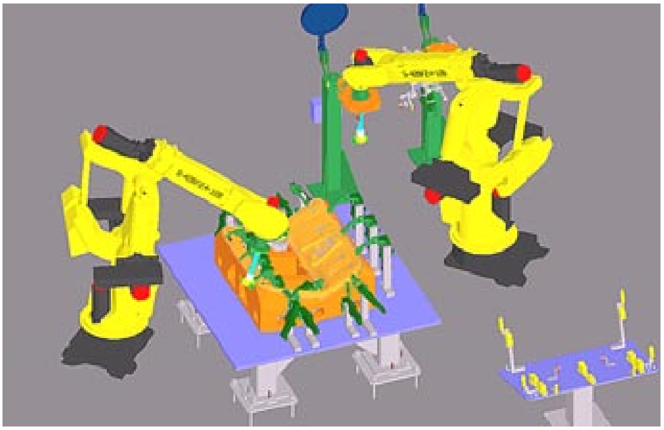

Figure 2. Virtual model of the test and verification equipment.

Project realization

Virtual models of the equipment and included products have been created. These models have been used for access simulations in a first step, followed by the creation of the robot paths. This off line programming is essential to get an accurate high speed robot program and can not be replaced by teach-in programming.

A specification of the product requirement necessary to enable high speed roller hemming has been developed through practical tests.

For the practical tests, for the verifications and to demonstrate the results, a robot cell has been installed at Innovatum Teknik AB in Trollhättan. This robot cell includes two robots and one hemming bed.

Project outcomes

Through the project, Saab has been established as a GM competence center in the area of roller hemming. Further, a new project within the MERA program has been initiated, focusing on the virtual verification system. Participants in this project are Saab, Svensk Verktygsteknik and Fraunhofer/Chalmers.

Participating parties and Contact person

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A process validation system for rollhemming

A process planning system for the roll hemming process of closures to the automotive business have been developed in this project.

Objective

Auto body components such as doors, hoods, fenders, etc. are typically formed from two pieces of sheet metal hemmed together at the peripheral edges. Hemming involves folding the edge of one panel over the edge of the other panel. Often, the hemmed sheets are also welded, soldered, glued, sealed, bolted, riveted, etc. to provide an additional connection between the pieces of sheet metal and further seal the edge to provide structural integrity and prevent migration of dirt and moisture between the joined sheets. There are several ways to achieve this hem, the most common method is through mechanical and hydraulic "table-top" press systems. A typical table-top system is shown in figure 1. The major drawback with conventional hemming is the high initial cost and low flexibility. Instead roller hemming is a technique that increases of use in the automotive industries production plants Rollhemming is mechanical method were a roller at robot arm gradually hem the flange over the inner panel. A schematic description of roller hemming is shown in figure 2 and more detailed description in figure 3.

The **advantages** of rollhemming versus conventional hemming are:

- Low initial investment cost (>40 % cheaper the conventional hemming system)
- Increased flexibility of the process
- Strong decrease in maintenance
- Increased quality of the hem

The **disadvantages** are:

- Low production rate
- Minimal knowledge of what factors and parameters that influence the quality of the hem and the rolling velocity.
- Virtual validation tools for design, engineering and production people are not available

The objective for this project is to develop an analysis and validation tool for rollhemming processes. A schematic description is shown in figure 4.

Results and deliverables

Now in September 2008 the first betaversion has been released with a brand new Graphical User Interfase (GUI) and new type of numerical algorithms which includes combination of dynamic multi body system and numerical algorithms for plastic deformations.

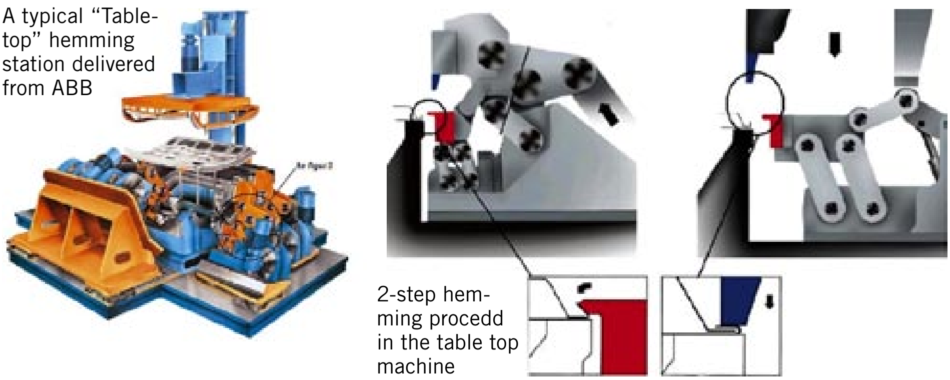

Figure 1 A table-top production unit for hemming from ABB

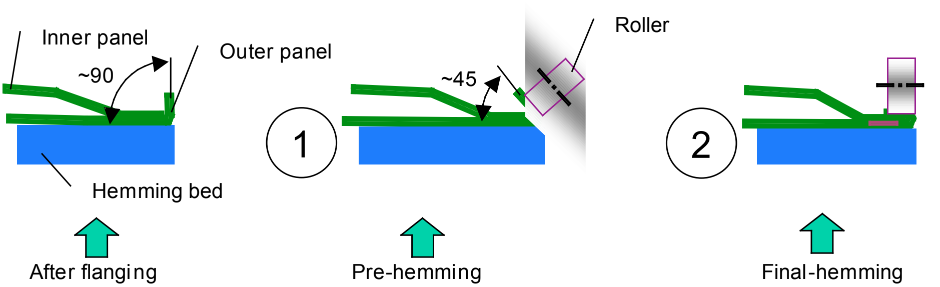

Figure 2 A schematic description of roller hemming process.

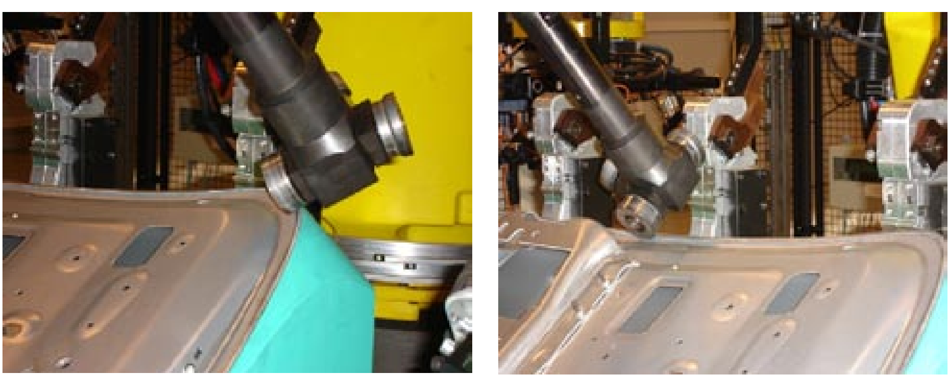

Figure 3 Description of the rollhemming process

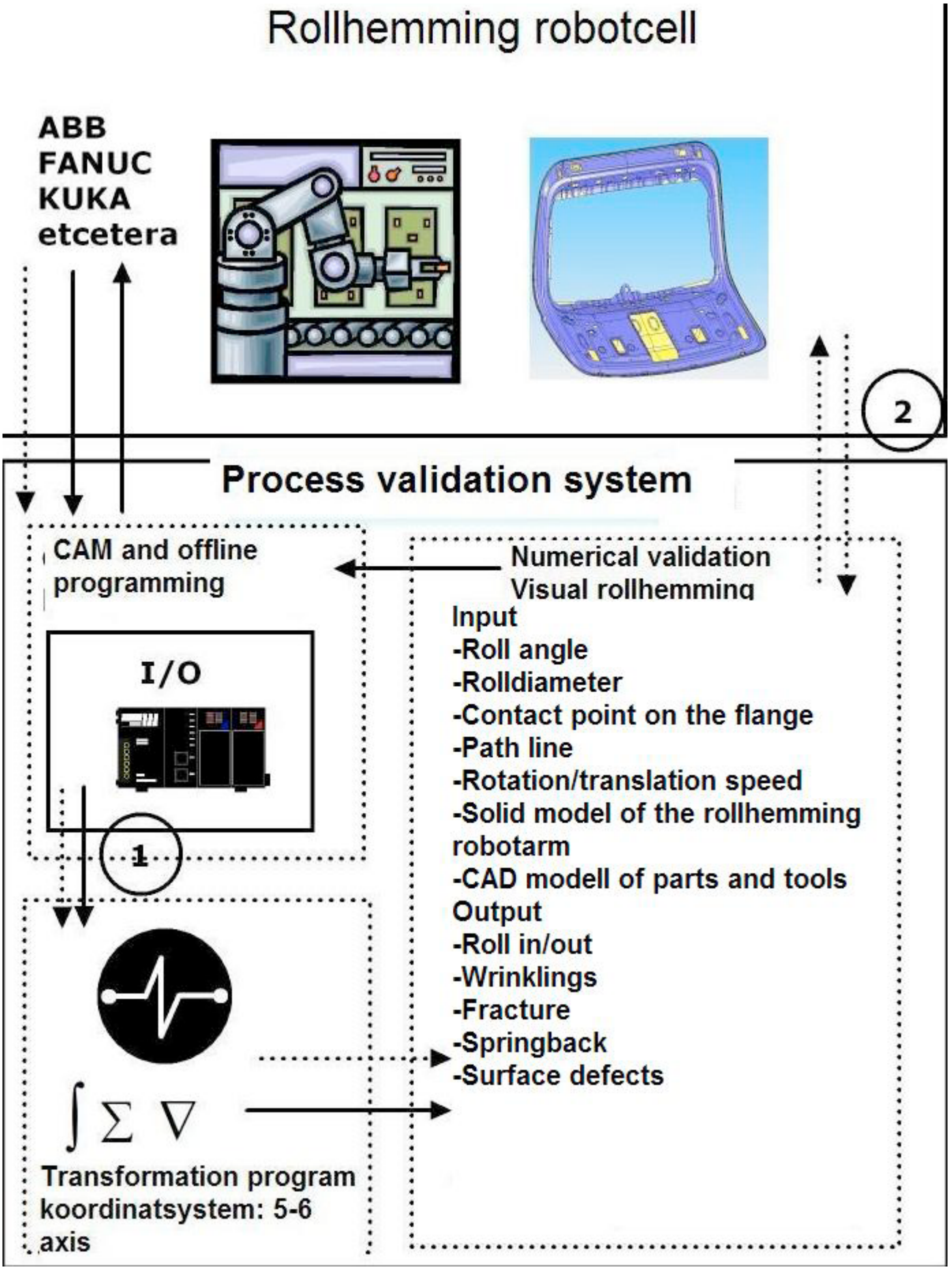

Figure 4 The schematic description of the validation tool that has been developed in this project.

Project realization

To confirm the process analyse system two new demonstrators were manufactured and together with a hood from Opel and a trunk lid from Saab Automobile the validation is u nder way and all geometries and strains will be compared between the physical part and numerical model.

Subsequently when this system is finalised it will be used for process planning of the roll hemming process around the world.

Project outcomes

Subsequently when the system is released it will be used for process planning of roll hemming processes around the world.

Participating parties and Contact person

Participants:

Name	Coordinator	
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Svensk Verktygsteknik	Roger Andersson	RTD partner

Contact person:

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R&D manager
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Quality assured curing of adhesive bonded car bodies

It is important to develop competitive knowledge about production processes and technologies in order to strengthen Swedish automotive competitiveness and contribute to continued production in Sweden. This project aims for strengthening of research directed towards solving problems occurring when bonding car bodies, particularly exterior panels, in the body shop process. The project is a joint project with Swedish car producer, academy and material and software suppliers.

The project scope covers two different subjects (1 and 2 below), and this report is disposed accordingly:

1. Simulation of structural adhesive bonding and resulting distortion from oven-curing
2. Glass balls in hem adhesive
3. Participating parties and contact persons
4. Publications and dissemination of results

1. Simulation of structural adhesive bonding and resulting distortion from oven-curing

Objective

Hemmed automotive parts like Door, Hood and Lid are typically adhesively bonded for two reasons. First, an adhesive with structural performance is applied in the hems before folding in order to improve component strength and prevent humidity penetration and corrosion. Second, a softer anti-flutter adhesive is used between inner and outer panels in order to prevent panel vibration. The anti-flutter is typically applied in several areas with limited inherent panel resistance to vibrations, such as areas with little or no sweep.

Both types of adhesives are typically applied in the Body Shop. The adhesives are normally one component heat cured adhesives. The curing can either take place in the Body Shop or in the Paint Shop ovens, but this work focuses on curing in the Paint Shop ovens and the resulting curing induced distortions.

During try-out of new closure panels, a significant amount of time is spent addressing the read-through effect caused by the oven curing of adhesives. In order to reduce both the try-out time and headcount needs it is desirable to have a virtual tool to aid in the early process optimization prior to the hardware phase.

Results and deliverables

The project has in order to create a simulation tool:

- Defined the material parameters that need to be included in a fundamental law for bonding, including the curing process.
- Developed experimental methods for numerical determination of those material parameters.
- Determined numerical data for five adhesives.
- Defined a fundamental law including the curing process.
- Implemented the material law in the software ABAQUS.
- Validated simulation results against experimental data for test specimens and for bonded car components.
- Evaluated a method/script for interpretation of simulation results.
- Developed reports, guidelines and documentation.

Project realization

Adhesive material parameters that are normally not available from adhesive suppliers have been defined and determined in lab environment using technologies as rheological measurement, DSC (differential scanning calorimetry), DMTA (dynamic-mechanical thermal analysis) and tensile tests. Simulations have been made in the software ABAQUS, and validated against lab specimens in steel and aluminium, and also with production hoods in steel and aluminium. Additional work is proposed to improve the tool.

Project outcomes

The simulation tool will make it possible to predict distortions that have not been possible to simulate before. That gives opportunities to reduce lead-time for new assemblies by early adaptation of design and choice of adhesive. The tool will also support quality improvements by better surface finish.

2. Glass balls in hem adhesive

Objective

Hemmed components (mainly hood, trunk lid and doors) are hem bonded. The adhesive contributes considerable to component stiffness. The curing can be made either in the existing Paint Shop ovens without adding cost, or in dedicated curing equipment in the Body Shop. The latter requires investment and variable cost. Uncured products are often insufficient stiff for the handling in the production flow from the Body Shop to the paint ovens, resulting in dimensional distortions. The solution has often been to invest in Body Shop curing directly after the hemming.

Earlier occasional tests have shown that hem adhesives with glass bead in some cases contribute to the component stiffness before curing. Our theory is that the glass is partially pressed into the metal surfaces when hemming, and in that way mechanically contributes to the shear strength. However, previous limited tests on products have given conflicting results. The project objective was to test out how to optimize parameters to achieve increased stiffness before curing.

Results and deliverables

The project has shown that glass bead adhesives can contribute considerable to strength in hem joints, and by that to stiffness before curing. The project also shows how the amount of contribution depends on different parameters as metal, amount of glass, hem type, hemming force etc. The report also formulates guidelines for glass bead adhesives in hem joints.

Project realization

The experimental evaluation of parameters has been made on special designed test specimens. The specimens were roller hemmed by robot at Innovatum, using a special designed tool that enabled accurate force control and recording of forces. The robot was programmed for the different tested hem types. Hem shear strength has been tested by IVF using a tensile testing machine.

Project outcomes

The sub project result will most likely result in increased usage of hem adhesive with glass filler, also in applications where we earlier didn't expect advantages. This will result in cost savings.

3. Participating parties and Contact person

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4. Publications and dissemination of results

Implementation has started especially for sub project 2 ”Glass balls in hem adhesive”. Information about results has been given at the Vinnova MERA conference Feb 2007, at a global CAE conference within GM Sept 2007, at the Swedish Welding Commission, AG 49 and in two numbers of the publication “Limforum” from Swerea IVF. A seminar was realized Dec 17, 2007 in Trollhättan, including possibility to participate on distance by webex. Vinnova and people from the companies represented by the partners were invited.

Quality, Optimisation and Cost-effective Welded Structures – KOST-2010

This project intend to develop technologies and methods for designing and manufacturing light weight vehicle structures and components in high strength materials in automated serial production. A new weld quality system have been developed and is now an open Volvo standard and have been introduced in IIW (International Institute of Welding) as a foundation for an international standard. Several systems for measurement and estimation of local weld geometry have been evaluated. A more robust process control for different types of welding processes will be studied and recommendations for process windows for serial production will be developed. With good surface weld local weld geometry in welded joints the weld root side will be critical. For that reason a good process control and a cost efficient NDT-strategies are required. Cost efficiency regarding robust designed product includes development of procedures and methods with integrated feedback to the design –and manufacturing processes. Together with accurate design methods for welded structures the results in the current project will contribute to cost efficient structures, a reduced material utilization and a increased knowledge.

Objective

The overall aims with the project are to develop conditions to introduce high strength material in welded structures through improved weld quality. Lighter and more effective products will improve the competitiveness for Swedish vehicle industry and suppliers of material and systems.

Project realization

The project is carried out together with a theme LOST within the VINNOVA program light materials and light weight structures. This includes the work package within laser-hybrid, five demonstrators and implementation of the results. The different work packages are briefly outlined below including LOST (WP7-13).

WP1: Development of relations between acceptance limits and fatigue life. Current weld quality rules have low precision which in some cases cause unnecessarily waste or failure in approved parts in service. In the WP a more scientific based system will be developed as a base for a new standard

WP2: Automation of quality assured weld and weld improvement processes. To achieve the desired weld quality under varying conditions, as varying heat transport, varying gaps a o, it is necessary to apply sensor technology and feed back from measured data together with parameterised simulation of the welding process.

WP3: **Analysis of cutting quality versus steel grade**. WP3 contain investigations of cutting quality in industrial applications with different cutting methods.

WP4: **Quality inspection system for weld geometry**. The quality is governed by the local outer geometry and mainly of the weld toe between weld material and plate. To measure the weld geometry a NDE-system, easy to use, is needed which rapidly and cost effectively determines, compares and documents the geometry.

WP5: Control strategy for internal defects. The NDT-technologies applied in many production systems today have not the capacity to assure the needed quality requirements for welds in more high strength material. The aim of this WP is to develop alternative NDT-system which includes both development of methods and procedures.

WP6: Influence from production methods on local geometry and residual stress state. To, produce welded joints, in a systematic way, with optimal performance related to fatigue life, knowledge about local geometry and residual stresses is required. The aim in this WP is to develop methods for generic residual stress distributions, and to describe the influences of stress distributions in a number of typical joints.

WP7: Development of a robust laser hybrid process. Development of a well defined process theory for evaluation of weld defects and parameter optimisations and an adapted platform for quality control by both NDE and process monitoring. The hybrid platform will be used for welding of the demonstrators WP8-10.

WP8-12. Five demonstrators of lightweight steel structures. The demonstrators are different welded components from Volvo CE, HIAB and Atlas Copco. Design and manufacturing are based on technology and methods from WP1-7 and the aim is to demonstrate weight reduction of 20-25 %

WP13: Education in and implementation of technology for design and manufacturing of lightweight welded structures. To improve the condition for the technology platform an education and seminar program will be performed during and after the end of the theme.

Results and deliverables

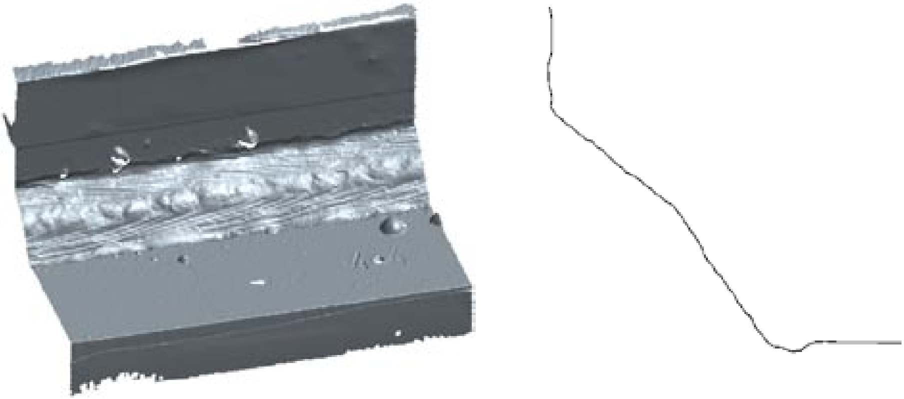

Fig. 1. A picture and a cross section of the weld geometry of a welded joint from a vision system for local weld geometry measurement.

Industrial results:

- A new weld class system have been developed and is currently an open Volvo corporate standard. The weld class system has been introduced in international conferences and will be considered as a foundation for international design code within the IIW.
- A number of different commercial vision systems have been tested and evaluated. For the moment several numbers of the vision systems have not fulfilled an industrial acceptable level regarding usability of the systems. Tailored software for measurement of the local weld geometry is lacking. A graphical user interface for evaluation of optically detected outer surface weld geometry has been initiated at HV.
- Results from fatigue testing at SSAB shows that modern cutting methods increase the fatigue strength of cut edges in high strength steel in comparison to current design codes.
- A creative networking within NDT with participants from manufactures, professionals and universities have been carried out. This showed that the main problem within utilization of NDT is probably not primary technical; it is rather related to the comprehensive procedure and the interdisciplinary nature of the NDT field. Designers, manufacturers and test engineers have often not similar outlook and starting point which lead to difficulties to understand and interpret each other. This is not fully surveyed yet within the vehicle - and manufacturing industry which will be the topic issued in WP5.

- An education for design-and analysis engineers within the industry have been carried out at KTH, Dept of Aeronautical and vehicle engineering, division of light weight structures. The course gives 6 hp university credits. The participants from the manufacturing industry where 24. The course will be given again in November 2008.

Academic results:

- PhD-students have been employed at LTU and HV to participate in the project.
- A Senior Lecturer have been recruited to CTH to develop NDT activity within LOST
- Zuheir Barsoum gave a PhD dissertation with the thesis title: Residual stress analysis and fatigue assessment of welded steel structures, april 2008. Barsoum is continuing as a research associate within LOST.
- Simulation routines have been developed in FEM for prediction of generic residual stress distributions in welded joints usually used within the industry.
- Fatigue testing at KTH of test coupons welded with different weld filler materials and welding processes shows that these have an influence on the weld defect occurrence, stress concentration and the fatigue strength
- A test series in order to categorize different types of weld defects have been carried out at HV.
- A new method, Bifurcation Flow Chart, have been developed at LTU in order to document and generalize welding data results and knowledge.
- Top modern 15 kW high effective fiber laser weling equipment have been installed at LTU. This system will enable effective welding of thicker material.

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- Methods for automatic inspection of weld geometry, Bachelor's thesis, report 2008:MR01, Mechatronics Engineering, Robotics and Embedded Systems, Department of Engineering Science, HV, 2008.
- Jonsson, B. and Samuelsson, J. A new weld class system, IIW doc. XIII-2235-08, IIW Annual Assembly Graz, Austria, 2008

Project outcomes

The fatigue strength based weld quality standard developed within the project is very promising in order to increase the reliability in welded structures. At the same time, over designed structures are avoided and new high strength materials can be utilized with precaution. The accuracy in the fatigue design of welded structures will increase within the whole Swedish manufacturing industry. This due to generation of more accurate material data, increased knowledge of modern fatigue improvement techniques and substantially better fatigue analysis and assessment methods, e.g. “effective notch stress method”.

Participating parties and Contact person

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ÅF Kontroll	Conny Ericsson
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Spot welding of high strength steel (UHSS)

High strength steel will increasingly be used for body production within the vehicle industry. These materials facilitate better performance e.g. improved crash performance and/or reduced weight. Reduced weight contributes to less environment impact and less fuel consumption.

Several new problems occur when spot welding those materials, problems that have not been observed for mild steels. Resistance spot welding is an established joining technology for sheet steels up to ca. 600MPa strength, but becomes more difficult at higher levels of strength.

The project aim is to increase knowledge about resistance spot welding (RSW) of these materials.

Objective

The project will develop new knowledge for industrial applications. This will facilitate an increased use of UHSS materials by presenting and verifying a solution to the problems that arise when spot welding these steels.

Results and deliverables

The project will be finished at the end of 2008. Most of the planned work is now done. The results and current status can now be summarized:

- Occurring weld defects in the studied steels, and combinations of these, have been identified.
- Process windows and process capability have been investigated. Parameters of importance for the occurrence of imperfections have been mapped. The mapping is an enabler for process optimization.
- A handbook for implementation of UHSS in production is being developed. It will be based on project results and realized implementations at project partners.
- A FEM model for prediction of cracks is developed and verified. Required material data have been generated. The simulation contributes with new valuable knowledge about why defects arise.
- Three techniques for NDT (Non Destructive Testing) have been investigated. The techniques are Ultra Sonic, Eddy Current and IR-Thermographie. Round robin tests have been made to study capability. Both manual and automated NDT have been examined.

- Mapping of how defects affect strength have been made. Static, dynamic and crash strength have been investigated, using FEM calculations and testing.
- Preliminary acceptance criteria for defects have been determined. Final criteria will be determined when all relevant project studies are ready.
- Selections of repair methods for defect spot welds have been examined.
- Development of documentation for training courses is in progress.

Project realization

The project is divided in ten subprojects (dp), aiming to achieve the targets. These sub projects are:

dp1. Identify occurring defect types.

dp2. Process optimization.

dp3. Implementation in industrial production.

dp4. Develop and verify FEM model to predict defects.

dp5. NDT for spot welds in UHSS.

dp6. How defects in RSW influence strength (static, crash and fatigue).

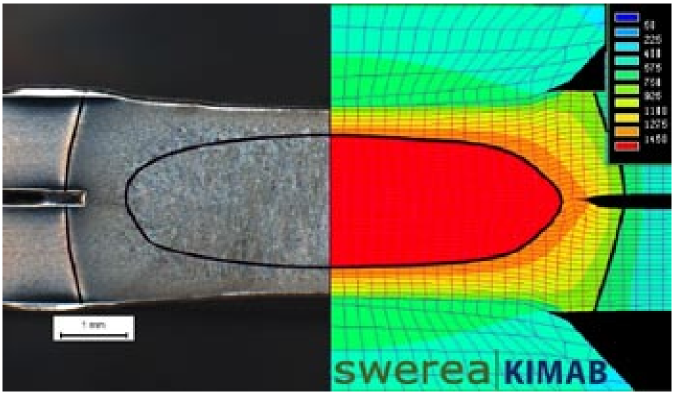
dp7. Formulate acceptance criteria for RSW of UHSS.

dp8. Repair of spot welds.

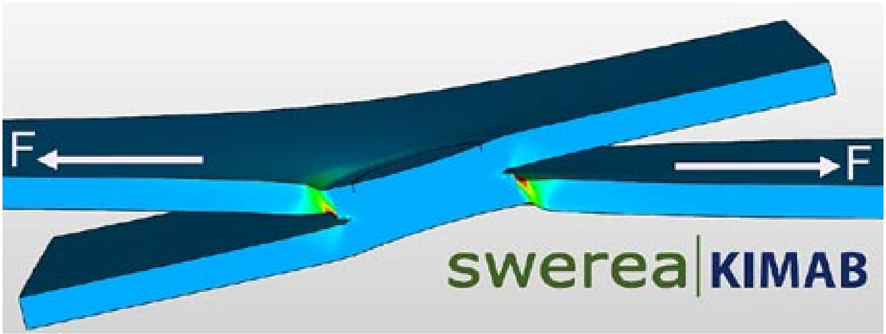
dp9. Training courses.

dp10. Project lead.

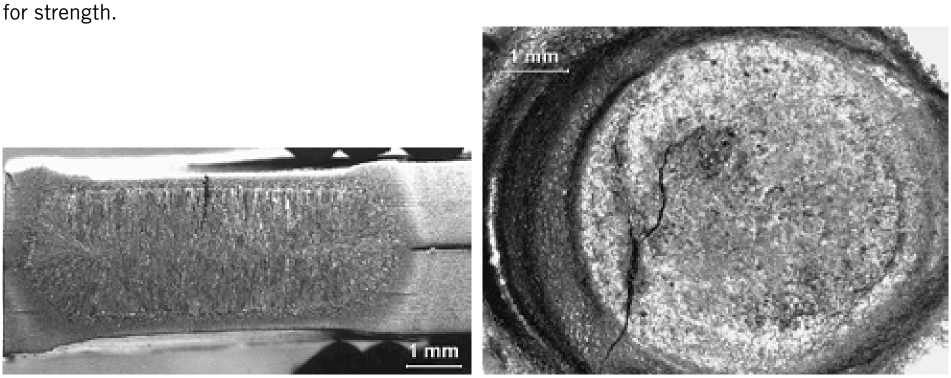
The project is planned to end Dec 2008.



Simulation of temperature during welding. The extremely rapid temperature change implies phase transformations in the material, resulting in volume changes which contribute to stress in the material. High tensile stress cause cracks. Simulations have improved the understanding of why and where cracks can be expected.



Simulation of tensile test of a spot weld with a surface crack. Simulations have together with tests contributed with new knowledge about which defects and locations of defects that are of importance for strength.



These photos show extremely large cracks in spot welds.

Project outcomes

The project results in methods, techniques and knowledge that facilitates an efficient introduction of UHSS steels in industrial production. It will contribute to and strengthen the partners and the vehicle industries competitiveness. It will also contribute to lighter vehicles and by that less environmental impact and lower fuel cost.

Participating parties and Contact person

Saab Automobile AB	Sven-Ove Olsson (project leader)
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Scania CV AB	Rikard Ottosson
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IVF Industriforskning och utveckling AB	Ola Albinsson
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Formblowing and Hardening, Process development

Formblowing and Hardening means heating of a rollformed tube in boron steel to 920 °C and then subsequently blow and harden the tube into a structural component with yield strength of about 1100 MPa.

Objective

The intention is to develop the Formblowing and Hardening technique into a production process

Results and deliverables

The Formblowing and Hardening technique make it possible to cost effective produce structural steel components with comparable weight/performance as hydroformed aluminum components.

Suitable components for Formblowing and Hardening are: A-, B- and C-pillars, roof bows, cross members, brackets, stays, bumper beams etc. The goal is to reach 20 % weight reduction compared to existing steel components.

Project realization

The development work have been divided into following parts:

Process development

Different methods for heating, handling, blowing and hardening of rollformed profiles have been valuated. Prototype equipment for Formblowing and Hardening have been designed, purchased and brought in operation. The work includes documentation of relations between internal gas pressure, material feed, workability and possible cycle time.

Tooling development

Methods for design and manufacturing of tools for hot forming, blowing and hardening have been documented. Effects of forming at 920 °C on friction conditions, tool wears and choice of tool material has been studied.

Forming try-out

Advantages and limitations with the Formblowing and Hardening technique are shown in LS-Dyna forming simulations. The result includes effects from hot boron steel characteristics, crack analysis, cooling from tool surfaces and water, spring back etc.

The simulations have been verified through forming try-outs and documentation of production parameters such as workability, possible radius, cycle times, tolerances and capability.

"Max Bulb"

The "Max Bulb" tool is build with movable tool parts. The intention was to avoid contact between hot material and cold tool as long as possible.

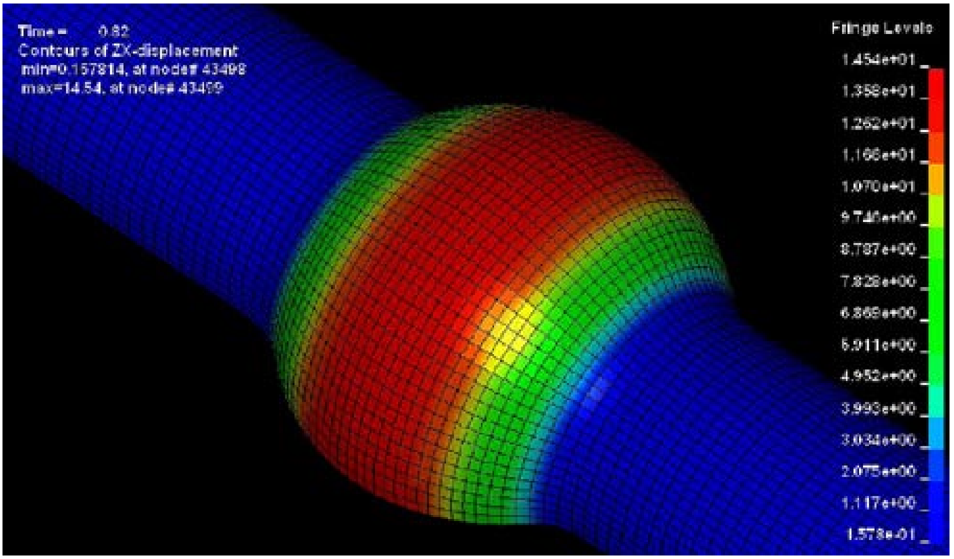
The obtained diameter change from 48 mm to 78 mm is large, more than 62 %.

Tube:
Boron steel 22MnB5 ø48 x 1.90 mm

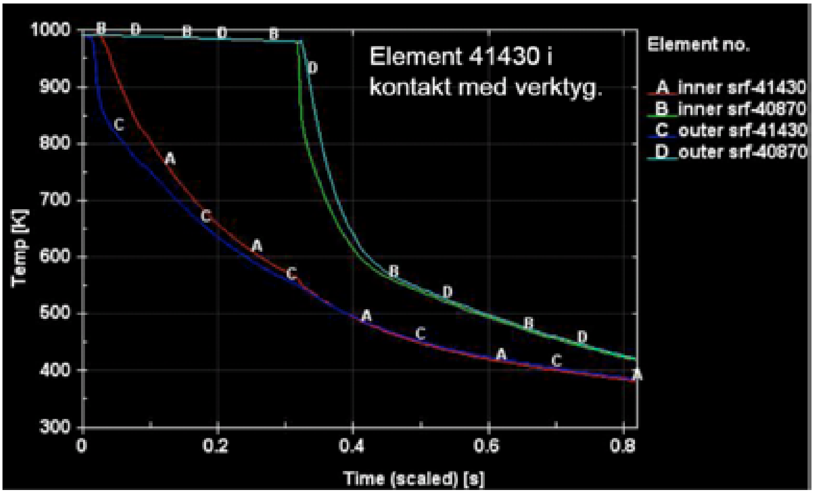
Formblown and Hardened:
Max diameter ø78 mm

Material thickness measured to 1.45 mm in centre of bulb.

Göran Lindkvist, candidate for the doctorate at Luleå University, has carried out thermo mechanical FE-simulations of "Max Bulb".



Thermo mechanical simulated tool. Maximum tool temperature is about ~ 240 C



Temperature Max-Bulb. Inner and outer surface areas with and without tooling contact. The water-cooling starts at time ~0.35 s.

Radius increase. Max radius 23 + 14.54 = 37.54 mm (Centre of material thickness)

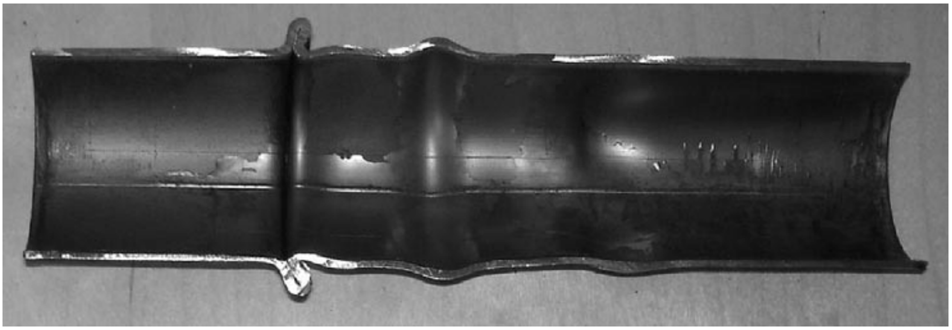
"Min Radius"

The purpose with "Min Radius" was to find minimum radius possible to form with the formblowing technology.

Tube:
Boron steel 22MnB5 ø48 x 1.90 mm

Formblown and Hardened:
Max diameter ø76 mm
Outer radius ~ 10 mm

Material thickness measured to 1.52 mm in centre of bulb.

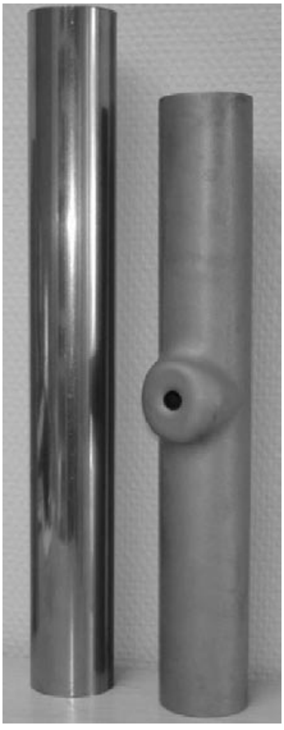


Test carried out with the "Show-piece" tool indicates that internal radius might be reduced to nearly zero depending on feeding of profile ends and tooling design.

"T-piece"

The "T-piece" tool equipped with a simple punching devise.

The purpose was to verify the possibility to formblown and harden a T-piece part and also to integrate a punching operation into the formblowing process.



Tube:
Boron steel 22MnB5 ø48 x 1.90 mm

Formblown and Hardened:
Bulb height 12 mm
Hole diameter 10 mm

Project outcomes

Project results has been reported in Licentiate Thesis, High temperature tribology of high strength boron steel and tool steels, Jens Hardell, Ltu 2007:36

Göran Lindkvist, Ltu, is expected to present "Formblowing simulation" Doctoral Thesis during autumn 2008.

Swedish vehicle manufactures is very interested in the Formblowing and Hardening technology. For discussed components (and prototypes) are potential weight reductions between 20 – 50 %.

Participating parties and Contact persons

Following Parties and Contact persons participate in the project:
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Persons below participate in the project reference group:
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Lena Larsson, Volvo Truck Corporation
Lars-Olof Hellgren, Saab Automobile

3D-roll forming of high-strength components with a varying cross-section

3D-roll forming is a newly developed method for forming of sheet metal components of complex geometries at a low cost. The objective of this project is to verify a robust process window as well as defining the formability limits of the method.

Objective

The objective is to develop 3D-roll forming of high-strength steel into a robust process for the Swedish automotive industry. Crucial steps in reaching the objective are to:

- Verify the process robustness and define the limits of the process
- Develop of a theoretical foundation to enable further development of methods for prediction of properties of the process and product.

3D-roll forming, developed and patented by the Swedish company Ortic 3D AB, is a novel method to roll form complex profile geometries. Roll forming is traditionally a very cost-effective way to form profiles with a constant cross-section. The fact that the method is suitable for forming of high-strength steel has raised the interest in it.

The novel method 3D-roll forming makes it possible to both vary the cross section of the profile and at the same time bend and twist the profile. This is something that significantly widens the usability of the method for the automotive industry. There is a need for cost-efficient high-strength crash beams with a varying cross-section. And since roll forming is well suited for forming high-strength steels, the lightweight demands can be satisfied.

Results and deliverables

The main result from the project will be new knowledge regarding

- The robustness of 3D-roll forming for high-strength materials and series production
- Formability limits of 3D-roll forming of high-strength sheet metal

The industrial contribution of the project lies mainly in delivering a verified forming method. It is therefore of uttermost importance to, in an accessible way, deliver information that a company can use to determine if a part is suitable for 3D-roll forming.

The academic contribution will be a better understanding of technical issues such as non-linear interactions of forming process parameters and material properties. This will be accomplished by a combination of physical testing and FE-analysis.

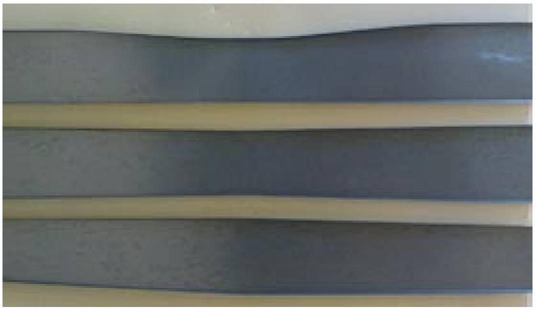
A presentation of mid-term results from the project has was given at the conference IDDRG2008.

Project realisation

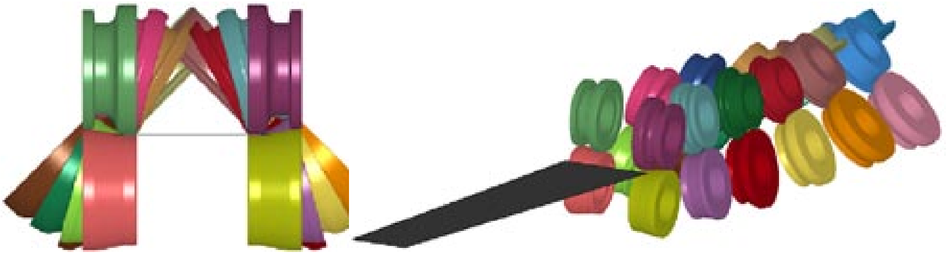
The project is based on a numerous set of experiments. The experiments are performed partly to decide the process' capability for series production, partly to find the formability limits of 3D-roll forming of different materials.

Two different types of basic profiles will be tested; a hat profile with large radius and a U-profile. These profiles are the basis in creating industrial components.

Demonstrator equipment (ref Ortic 3D)



Five geometry variants formed in one set of tooling
Project outcome



Process set-up for FE simulation of the 3D-roll forming

Project outcome

The project will create opportunities for

- Reduced lead time
- Lower investment costs
- Increased flexibility

for the Swedish sheet metal forming industry by increasing the knowledge of possibilities and limitations of a new forming method, 3D-roll forming.

The potential of 3D-roll forming lies in the combination of a low cost method such as roll-forming, and advanced steering of roll position to make creation of complex roll-formed profiles possible.

Participating parties and Contact person

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Saab Automobile AB	Anders Malm
Volvo Car Corporation	Paul Jonason
SSAB Tunnplåt AB	Lars Troive
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Enhanced manufacturing by utilisation of laser-hybrid welding – PROHYB

Laser-hybrid welding is a new technology where the laser is supported by another welding process, the two processes are combined in one welding zone. This enables large benefits in terms of tolerances and productivity. This project is a feasibility study for implementation on thin sheet designs, i.e. the vehicle industry and suppliers.

Objective

The objective is to create state of the art manufacturing and productivity improvements by adapting and implementing new technology in the Swedish vehicle industry. By combining achievable product and productivity improvements, a giant leap in manufacturing is at hand.

Tasks for the project:

- To study the terms and possibilities for manufacturing of vehicle components in thin sheet steel by laser-hybrid welding, i.e. Laser-MAG
- To improve the weldability of coated steels
- To study and further develop the gas shield in the process

Results

The project has created vital knowledge for the vehicle industry and improved the competitiveness for the Swedish industry. More specifically, the project expects to:

- Increase the productivity for manufacturing of vehicle components
- Increase the process robustness
- Enable more versatile manufacturing
- Enable improved properties for the vehicle components (geometrical quality, stiffness, etc)
- Estimate the economic manufacturing economy for the process

Project realization

The project consists of 7 modules:

A1. Pre-study of component, application and process.

A2. Process mechanism study where dynamics in the material transfer, plasma and weld pool stability is studied. Influences on penetration, microstructure and robustness are evaluated.

A3. Redesign and adaptation of components.

A4. Verification of process on sub-components.

A5. Manufacturing of selected component.s

A6. Evaluation of joint properties, manufacturing system and design. Cost calculations.

A7 Reporting and presentation of results.

The project is running until December 2008.

Project outcome

The project is still active in modules A6 and A7. So far, it has been shown that high productivity and improved gap bridging can be reached as well as better tolerances. To be able to use the process potential fully, redesign of the product and an adaptation of the manufacturing are necessary. These aspects are studied now in the project, together with economic aspects on the process and manufacturing. The project has shown that the process has advantages also in the thin-sheet range and gathered knowledge on the terms for successful implementation. Results have been presented externally at a joining seminar in Gothenburg in April, and at a seminar arranged by the Swedish Welding Commission. More result spreading activities will be performed after the final evaluations.

Participating parties and Contact person

Gestamp HardTech AB	Jan Krispinsson (projektledare)
Volvo Personvagnar AB	Johnny K Larsson
Permanova Lasersystem AB	Urban Todal
ESAB AB	Johan Tolling
AGA AB	Kjell-Arne Persson
KIMAB (Korrosions och Metallforskningsinstitutet AB)	Joakim Hedegård

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Swedish Handbook in Screw Joint Technology

A Swedish Handbook in Screw Joint Technology will be developed as a web based application. In this MERA project Design of Screw Joints is in focus. It will be established by the following project partners: Saab Automobile, Scania CV, Volvo Power train (AB Volvo), Volvo Cars, Atlas Copco and Bulten. Best practice from each company will be identified and a common Swedish view will be developed and published in a web application developed by Swerea IVF.

Objective

The objective is to create a common view with regard to screw joints and to make us more globally competitive when it comes to screw joint design.

Results and deliverables

Guide lines and recommendations have been generated and a web based handbook is on its way, see e.g. chapter "Gängingrepp" in the "Handbok" section of the Swedish Fasteners Network (SFN) web site, see link: http://extra.ivf.se/sfnskruv/

Project realization

Review of best practice within each company, work group meetings and the development of Swedish definitions, guide lines and recommendations for screw joints. The web application will be developed and hosted by Swerea IVF. Taking pictures and making illustrations that will fit the web based interface. Publishing guide lines and recommendations from 20 important areas (chapters) within screw joint design.

Swedish Fastener Network (SFN)

The web application will also be the home page of the Swedish Fasteners Network (SFN). The site will host other project reports generated within the network. For example the SFN MERA report of Ultrasonic Audit of Yield Point Tightened Screw Joints (UTskruv, Dnr2007-02859). Figure 1 below illustrates the generic structure of the web site:

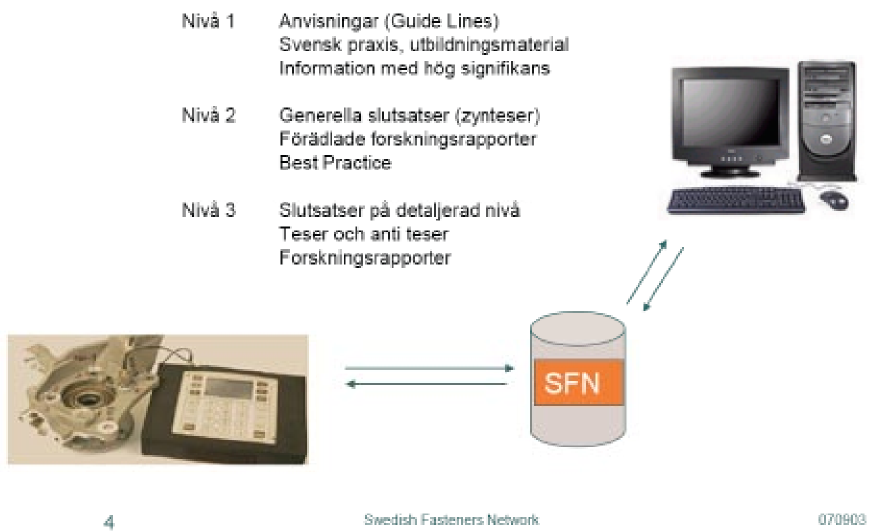

Figure 1. Schematic illustration of the web based SFN site.

Project outcomes

The web application is the project outcome. The level 1 information will be reachable for everyone having an internet program on their computer. The level 2 results will be possible to read for all SFN company employees. The level 3 information is applied with a pass word and can only be studied by the project partners.

Participating parties and Contact person

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SAAB Automobile/GM Power Train, Göran Toth
Atlas Copco Tools, Carl Carlin
Volvo Power Train Corporation (AB Volvo), Filip Bergman
Finnveden Bulten, Kurt Andersson

Development of Ultra sound velocity technology for Yield point tightening (UTSkruv)

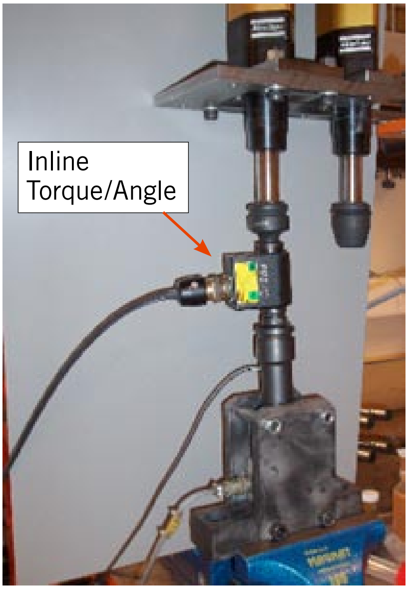
Today screw joints in chassie applications are only utilised up to 30 %. In order to increase this to 60 % of the strength of the screw yield point tightening should be utilised. This means that the joints are mounted to initial plastic yielding.

Aim

The purpose of this project is to prepare the way for advanced yield point tightening in Swedish engineering industry. This is done by building knowledge on in-line ultra sound inspection for yield point tightening.

Results

Equipment has been built for instrumented yield point tightening. It allows simultaneous measurement of torque, force and time of flight for the ultra sound signal.



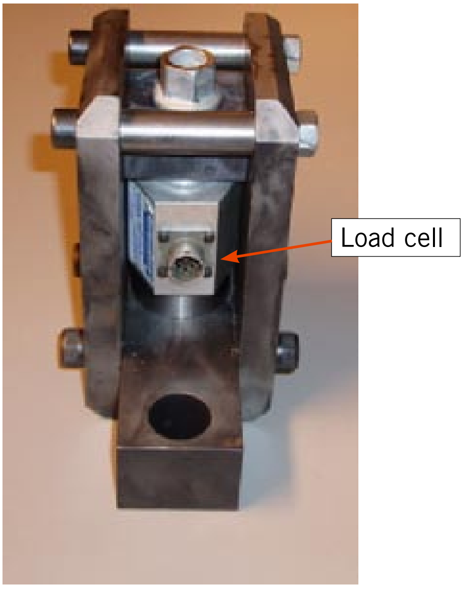


Fig 1 Instrumented equipment.

Finite element models were built for the screw joint. The results of the calculations were verified with experimental evaluations.

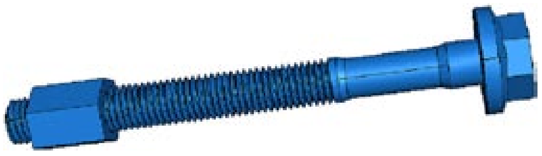


Fig 2 Three-dimensional model of screw joint

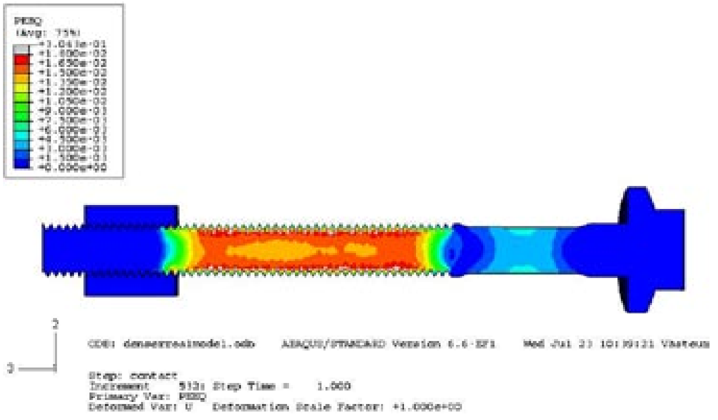


Fig 3 The model during tightening.

Project effects

This project is a small pre study in the MERA programme. The purpose is to check the possibility to build advanced models for yield point tightening. It is the purpose to use the models in future projects on development of yield point tightening technology.

In the project it was shown that it is possible to build the models and that they show good agreement with experimental data.

Parters och contact person

Project leader:
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Other partners:

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GM Power Train	Göran Toth
Atlas Copco Tools	Carl Carlin
Volvo Power Train Corporation	Filip Bergman
Finnveden Bulten	Kurt Andersson

Development of Competitiveness for Saab Automobiles production in Sweden, domain I and domain II

In order for Saab Automobile's production and development to continue in Trollhättan production technology and development processes must be world class in order to compete in the increasingly difficult competitiveness globalization brings. This requires initially quick and effective development which lies within the motive for MERA programs formation. In order to achieve this a number of smaller sub-projects have been completed within Domain I 'Specific manufacturing processes and integrated production development' and Domain ll 'Development and running of manufacturing processes with virtual and digitial support'.

Objective

This project is composed of a number of sub-projects directed towards relatively new manufacturing processes. These processes were evaluated and the results used within current production, as feedback to product development and as the basis to define the need for additional development projects.

Project realization and results

The project is composed of seven sub-projects.

D.I-1 Roller Hemming

This sub-project has developed process driven product requirements which can be used to secure the defined targets for quality and investment using this relatively new process. The project team participated in pre-series production of new products in order to capture the necessary competencies and information which today lies only in a few external suppliers for production equipment for roller hemming. Furthermore, has the area of product form been investigated with respect to the possibility of using roller hemming. Evaluation of cost for purchasing and re-use of roller hemming equipment has also enabled guidelines to be developed for further use of roller hemming as a mainstream hemming method. This sub-project has initiated a significantly more focused and in-depth MERA project "Metal sheet roller hemming for high production volumes".

D.I-2 Glass Bead Adhesive

The project idea is to use adhesive with glass beads, and thereby achieve sufficient bonding strength of assembled hang-on parts in the body shop without having to harden the adhesive. Adhesive with glass beads is applied prior to the hemming station. The glass beads are partially pressed into the sheet metal which are hemmed, and thereby forming a mechanical bond with sufficient stiffness to enable handling of the assembly in subsequent operations until hardening in the paint shop ovens.

The project has verified that adhesive with glass beads achieve the previously mentioned advantages through evaluation of process feasibility, evaluation of dimensional stability and evaluation of wear on the equipment

This sub-project has initiated a more in-depth study found in MERA project "Quality assured curing of adhesive bonded car bodies".

D.I-3 C-Weld

The first step in a body assembly is that the single parts are fixed in location to a geometrically stable body and are then welded together. Ideally, the welding should occur near the fixation points. This sub-project focuses on developing a concept to combine fixation and welding in a single step in order to improve dimensional data, reduce investment need, reduce floorspace and increase product mix flexibility. The project delivered a feasible concept currently under patent application and a prototype of a combined fixation/ welding apparatus.

D.I-4 Vision guided robot

This sub-project was successfully completed in Jan 2006 with final project results being presented in Trollhättan, Ruesselsheim and Detroit. The main purpose of the project was to identify areas where further development and use of vision guided material handling would increase flexibility and productivity with reduced investment. This goal was achieved, documented and presented within GM. Because of the potential found in this study, two more in-depth MERA project was initated; "Automated body shop material handling" and "Flexible Lineside Material Supply", were an extensive exchange of knowledge with universities and Swedish companies has taken place.

D.I-5 Hydroforming Pre-Study

The purpose of this study was to assess the potential to reduce tooling investment for sheet metal forming tools in low volumes via sheet hydroforming technology. A decision tree document was developed and a decision made to continue work internally with a physical test of a door panel in a Quintus press to verify the finish quality prior to developing further the business case and actual test in low volume production.

D.II-1 Simulation of Fatigue in MIG welds

This sub-project has developed a method for creating a FEM model technique which can be used to predict fatigue life in MIG welds in body parts. This type of analysis capability gives the possibility to optimize the weld process with respect to strength and fatigue, which can reduce the need for physical testing and thereby reduce the development time.

D.II-2 Stochastic FE-simulation for sheet metal forming

The work in this sub-project has been a cooperation between Saab and IVF. The work defined the basis for stochastic simulation and implementation of this methodology in sheet metal forming simulation. This work is the basis of one work package in the more exhaustive MERA project" FE simulation of sheet metal forming".

Project outcomes

The project has been a catalyst in the process of establishing Saab as a research and development resource within GM. It has also meant expanded contacts and net work building with Swedish universities and industrial companies. Some of the sub projects has delivered results that could be used directly by the production organisation at Saab, while other sub projects has been pre studies leading to more extensive research projects with the participation from Swedish institutes and universities.

Participating parties and Contact person

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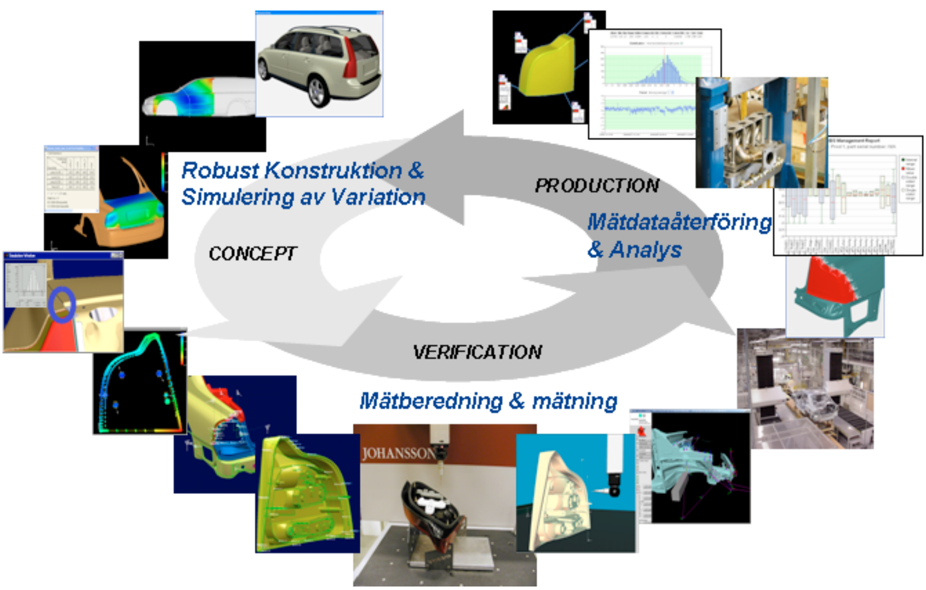
MERA conference 2008

Technologies for geometry assurance and metrology

Industrial Program for Geometry Assurance

To consistently manage geometric variation in a complex product within a computer-based environment is a key factor to experience and shortening lead time in the development and introduction of new products in the industry. A virtual product and process chain with a large element of knowledge and experience gained in previous products is a necessity to increase competitiveness. Automotive companies invest heavily in an integrated geometry assurance process and virtual methods to achieve FPC (First Part Correct), namely that from the start of production of components and assembly process provide qualified products that meet product requirements. So far, the automotive companies own work and the research work show very good effects. However, it has been concluded that most of the product processing work is done in active collaboration with external partners and suppliers. To obtain full benefits of geometry assurance there must be methods, techniques and practices widely disseminated among the suppliers. The project "Industrial program for Geometry Assurance" is an initiative to gather customer business and active supplier companies to develop materials and resources to adapt technologies and methods for SMEs. In addition, to include experience we have to create conditions for a broad industrial competence development.



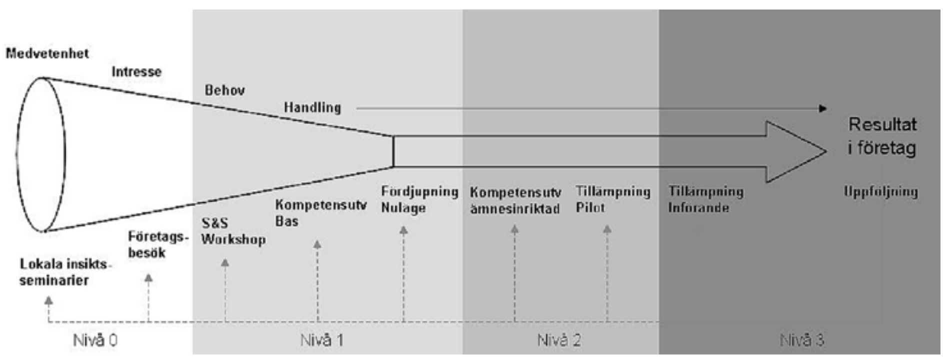
To minimize the effect of geometrical variation in complex products with an integrated geometry assurance process is important for Swedish companies' competitiveness.

Objective

The aim has been to start up technology dissemination work and build up a resource to implement methods and techniques. To be able to reach out to a larger mass of companies by using industrial tools for a coherent geometry assurance process to realize the future requirements of development and manufacturing. Through an active interaction with the customer, pilot enterprises and training performers the objectives has been to create conditions for broad industrial development and create good example and experience of a change. Thereby improving prospects for a good geometry assurance personal and corporate geometry processes, leading to shorter development cycles, shorter running times in production, lower quality disturbances, better use of resources, etc.

Results and deliverables

Based on research results and the experience within the field of geometry assurance, techniques for dissemination and training materials has been created with appropriate, practical demonstrations of methods, techniques and procedures. A model for active dissemination techniques have been developed and spread and to some parts tested on the participating companies.



Developed research results has been verified and adapted for the small business conditions and a typical supplier situation. Technology and methods have to be applied in practical pilot projects demonstrated the methods, techniques and procedures that can be applied in different situations. The idea has been to use the participating companies as Reference Company and together create the Swedish model for geometry assurance, so that other industries can find how to apply technology and practices to create a competitive advantage. At the same time, resources and experience is created for a broad industrial dissemination.

Project realization

The starting point has been the already ongoing research in the area geometry assurance, to minimize the effect of geometric variations, especially by the research group that was established in the project "3D Tolerance Management" (1997-2004) (Chalmers Wingquist Laboratory, Swerea IVF, Fraunhofer Chalmers Centre for Industrial Mathematics) in active collaboration with leading companies through joint projects funded both by the industry, SSF and VINNOVA.

It's necessary to gather the resources already present in the area and create a network of performers at various levels to reach companies with the same message. Industrial program for Geometry Assurance, Phase 1 in the MERA program has put foundation for technology dissemination materials and training materials.

In order to achieve success within companies that actually has to make a big change, requires more purposeful skills and implementation, that in different ways can provide companies with insight into what's to gain by introducing methods of geometry assurance and a structured process geometry. Broad dissemination seminars on a comprehensive level must be combined with more detailed demonstrations and briefings on what is necessary to create an integrated geometry assurance process and a effective geometry work. At the same time, the positive effects must always be demonstrated to create a positive change.

Technology and methods have therefore to be applied in practical pilot companies showing how the methods, techniques and procedures can be applied in different situations.

The focus of the pilot projects have been among others:

- Robust design and simulation of variation
- Infrastructure for the measurement geometry and measurement results
- Measurement, which validates requirements and deliver the right information content
- The use of geometric measurement results

The pilot projects have yielded the same time experience of how imposing the problem looks in different situations and given the opportunity to disseminate the skills of more committed individuals to build a resource to be able to actively help enterprises in their change.

Project outcomes

Research results have, in addition to purely technical achievements, already shown companies that consistently work with their geometry system produces a lot of synergies which will primarily get them to know their products and processes in a more realistic way. It is clear that cooperation between the actors must work so that:

- information flow for the geometric information is clear and functioning
- simulation results and measurement results are stored and handled in a structured way
- measurement results are reusable and traceable
- results of various kinds are available to all

It is then important to create the technical infrastructure, which gives everyone access to timely and relevant geometric information. Businesses and users have to learn how to use simulations and data as a source of information in the development process. It is important to understand the big picture and see the common thread between the different activities. This introductory material has been very useful and created a better understanding and increased dialogue between the different functions of the companies.

Among one of the effects attention around geometry assurance thinking creates in a company, are the opportunities that simulation of geometry effects can give to the understanding of their own process. In one of the pilot companies in the project, we looked on how the data from the form filling simulation showing how the part is skewed, as input in the variation simulation. It was found and verified in the project that the correlation between simulated outcome was more than convincing, when we compared the simulated part with a real part in it's environment. We found that the difference between simulated and real outcomes was approximately 0.02 mm in the cases we studied, which surprised the developers at the company. The results of the study makes the pilot companies willing to participating in future research projects for non-rigid simulation.

Another effect that is very clear is that the availability of data creates a better discussion. Sure, there have been and are many views on how best to present different things but certainly have discussions gained momentum on the product and process alive, and what you can do for improvements / adjustments and how it connects back to the product requirements picture. This is probably one of the main effects. Now debating whether the process is viable or why it looks a certain way. Decisions and actions can be supported with data and one can also see the results of operations.

A steady improvement has started!

Participating parties and Contact person

Företag	Kontaktpersoner, titel
Volvo Car Corporation	Björn Mattson, Director Quality and Geometry: Manufacturing Niklas Wemdal Manager Geometry Assurance: Manufacturing
Saab Automobile AB	Jon Höglind Manager Manufacturing Engineering CQA Thn Peter Josefsson, Project Manager Central Quality Assurance GME Bo Anulf Integration Manager
Scania AB	Bertil Tamm, Method Responsible Assembly Assurance
Volvo AB	Johan Granath, Group Manager Anders Ydergård, Senior Vice President Volvo 3P Product Development
Ericsson AB	Lennart Schön Specialist Building Practises
Faurecia Exhaust System AB	Lars Hammar Quality Manager; Technical Centre
Plastal AB	Daniel Johansson Manager Quality Engineering

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SIMET – Swedish Industrial Metrology Forum

Metrology and management of measured data are key factors for keeping quality at a high level and minimizing cost for scrap. This fact is not always realized by the industry as they tend to look at metrology as a cost increasing factor rather than the tool to avoid hassle and costs for quality losses. Metrology is not just a process of measurement that is applied to an end product. It should also be one of the considerations taken into account at the design stage. With the recently introduced Geometrical Product Specification (GPS) model, tolerancing and uncertainty issues should be taken into account during all stages of design, manufacture and testing. The most compelling reason is that it is often considerably more expensive to re-engineer a product at a later stage when it is found that it is difficult to measure, compared to designing at the start with the needs of metrology in mind. Measurement Planning has therefore been selected as the main topic for the SIMET research activity. Through workshops and integration with production units in industry a general principle is now being developed for the Measurement Planning process.

In addition to the mission of bringing Measurement Planning to the Swedish industry, SIMET plays a key role for bringing Swedish Metrology users and vendors together under the www.simet.se portal. It enhances interaction between different players in the dimensional metrology field, it raises competence by introducing new courses and skills and opens up for insight and discussion about forthcoming ISO-standards in the GPS-field. SIMET has also undertaken the role for development of modern metrology courses for students at Technical Universities in Sweden, and acts as an agency for master thesis work proposals, job offers and training.

The SIMET project is managed by an executive board representing Hexagon Metrology Nordic AB, KTH, Mitutoyo Scandinavia AB, Saab Aerostructures, Scania CV, SP - Sveriges Forsknings och Provningsinstitut, Swerea-IVF, and Volvo CE.

Objective

The objective of SIMET is to be The National Centre for information, knowledge, education, research and joint activities in industrial manufacturing metrology. Initially the efforts are concentrated on dimensional metrology, but it might be expanded to industrial metrology in general if proved to be successful. It shall be a neutral cooperative organization for industry, research and educational organizations, and official authorities with the objective of promoting Swedish metrology.

Explicit objectives are:

- Establishment of a web based platform for interaction between industrial metrology partners in Sweden
- Secure the industrial need of well educated and competent metrology technicians and engineers by development of new and updated courses in industrial metrology.
- Be responsive to joint or partner specific needs in research and education, and create professional courses and research projects with funding.

Results and deliverables

The results of the SIMET project are divided into three categories: - development of education packages, research on measurement planning and the establishment of the SIMET information exchange forum.

The education package has been based on the needs presented by the industry partners, and contains five courses that will be available at technical universities in Sweden from 2010. The courses rely to a great extent on the new ISO-Geometrical Product Specification model and its standards. The five courses are:

- Metrology in design and manufacturing (9 credits)
- Modern measurement techniques (6 credits
- Specification and tolerancing of length, form, position and surface structure (6 hp)
- Measurement uncertainty and management of measured data (6 hp)
- Statistics for metrology engineers (3 hp)

Course moments to be included in this education package are already being implemented in ongoing manufacturing courses at KTH. In particular "think verification" is envisioned in the overall chain from product idea to design and manufacturing.

The research action within SIMET is focused on the Measurement Planning process. This was obvious after investigating different needs among the industry partners. Surprisingly little research has been done in this area and there exist only one rather rudimentary standard the ASME B89.7.2-1999,"Dimensional Measurement Planning." The research is carried out in close collaboration with the MERA ModArt project developing "Pilots" for production planning. Two articles and two workshops have been presented so far, and two more articles will cover case studies.

The information exchange platform at www.simet.se provides members with a forum for discussion about measurement problems, standards, new techniques and much more. Here, new metrology literature is presented and draft ISO-standards can be reviewed and commented. Available courses and events are listed as well as job opportunities and master thesis jobs. Current metrology research and tools for interactive verification of coordinate measuring machines is given.

Project realization

The project is operated by a board of eight members from the partners with monthly telephone or physical meetings. Two work groups deal with information/advertisement and research/educational tasks. The research is carried out by one PhD student in collaboration with industry through workshops and physical visits, and the results are presented at conferences as well as in proceedings and journals. The education package is developed by joint work between KTH, SP and Swerea-IVF. The SIMET web-based information exchange platform has been developed at KTH and is also currently operated from KTH.

Project outcomes

The major impact of the SIMET project for the industry is that they are slowly realizing the importance of bringing metrology into the entire design and production process. Cost savings of up to 30 % are expected by proper implementation of the measurement planning process. The renewed interest for metrology is backed up by the educational efforts and will reduce the impact of the retiring senior metrology technicians, and those technicians in need for raising their metrology competence can gain a lot from the SIMET platform and its forum for information exchange.

Participating parties and Contact person

Participating partners are:
Hexagon Metrology Nordic AB, KTH-DMMS, Production Engineering, FOI, Mitutoyo Scandinavia AB, Marposs AB, Saab Aerostructures, Sandvik Utbildning AB, Scania CV, Volvo Powertrain, Tool Center Försäljnings AB, Volvo Construction Equipment AB, SP-Sveriges Tekniska Forskningsinstitut, Swerea-IVF, and SIS

The SIMET-project is managed by KTH and the contact person is:
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L-FAM, -Lightweight Fixtures and Grippers

The mechanical properties of conventional fixtures, in particular in automotive industry, are an important parameter that restrict the way the process can be planned. Conventional fixtures, normally made out of steel, are heavy and require extensive measures to meet the demands of flexibility and productivity.

New lightweight technology, initiated by AB Volvo (Trucks), shows that by introducing new materials and innovative designs productivity and flexibility can be improved. The lightweight composite equipment are tougher, stronger and significantly lighter compared to conventional steel fixtures. By utilizing the enhanced mechanical properties production can be planned differently and thereby productivity and flexibility are improved.

The results of the project will be implemented in full scale during 2009, AB Volvo is building a new assembly line based on the new lightweight technology. The line will be in full service 4th quarter 2009.

Objective

The motivation of this project is to introduce and study novel "light weight" carbon fibre based fixtures in the assembly lines to create possibilities for: -decreased investments in assembly equipment, -an increased flexibility of assembly line planning, -a decrease of production time, -an improvement of ergonomics in manual assembly and -an increased geometrical variation of assembled products in the automotive industry.

Results and deliverables

The project have resulted in a industrialization of the lightweight technology. Materials, quality systems, design- and manufacturing - methods have been improved resulting in a commercial available technology.

Project outcomes

The technology is in use in a pilot line at AB Volvo and have so far produced more than 7000 truck cabs. In addition equipment are installed at AB Volvo USA, Volvo Cars Gent and manual equipment is used at AB Volvo both in Umeå and Gent. Throughout the project a number of demonstrators have been manufactured and evaluated.

Assembly of large structures at Volvo Truck in Umeå. The average weight of the light weight fixture and part to assembly is 200 kg. The supporting carbon fibre frame is 60 kg, less than 10 % of the corresponding traditional steel designs used today.

Participating parties and Contact person

Flexprop AB	Karl-Otto Strömberg, co-project manager
Halmstad University	Bengt-Göran Rosén, project manager, bg.rosen@set.hh.se
Volvo AB	Håkan Sundberg
Volvo Cars Inc.	Pernilla Dittmer

Also, SICOMP -Swedish Institute of Composites, Alfgam Optimering och University of Huddersfield, UK participate in the project.

Advance Geometry verification by parametric measuring principals

By using standardize measuring methods rules, Coordinate measuring machine programming can be automated.

Objective

This will dramatically reduce the CMM programming time.

Provide a library with standardized measuring rules that also secure correlation between different providers.

Deliver a tool for Auto generation of measuring path Results and deliverables

Results and deliverables

We expect to short total lead-time 5 times by automate the offline programming process.

We also expect to short the total measuring time by up to 20 % by optimise the programs.

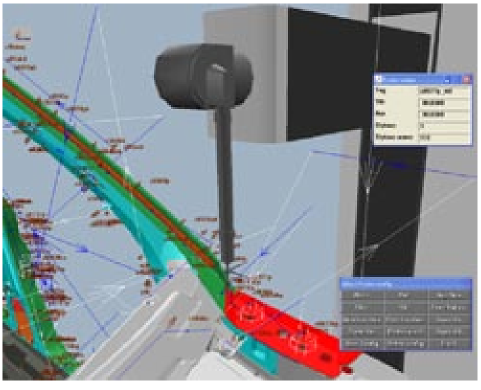
Project realization

Investigate measuring methods used by selected providers.

Tune methods to fit in to a atomised process

Nominated methods will be documented and integrated in the tools.

Tests will be made in demonstrators.



Measuring Rule Ex.
Hole feature.

Normally the hole needs to project on to the plane.
Move and rotate the coordinate system to center of the hole with Z normal to the plane
Measure the 3-4 points around the hole.
Now align the coordinate system to the plane
Measure 3-6 points inside the hole - 0.4 mm from the plane.
Create a new circle projected on to the plane.
Recall Part coordinate system
Report the projected point and the diameter.
Rapportera ut den projicerade punkten samt diametern.
Evaluate and analyze True Position or coord. Tolerance according to the Requirement.

Project outcomes

The project is rated as high interest from the mother companies of Saab and Volvo and will put us in a lead position.

Participating parties and Contact person

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Participant Akamedi:
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Rickard Söderberg Wingqvist Laboratory Chalmers
Fredrik Wanderbäck Swerea IVF

Digital Linked Process – Knowledge based feed back, DLP-E

This project shall create the prerequisites for the vision about the self learning process.

Objective

The objective with this project is to perform a pre-study to create the prerequisites to take a big step towards the vision – the self learning process. This shall be done by developing a digital and physical process to control the process and the production development on a general level based upon production results. It shall also be done by creating a more efficient CAM development. By developing a process for knowledge based preplanning. To be able to verify the results, the conclusions, a concept environment shall be built up for testing.

Results and deliverables

Industrial:

- Test environments has been set up for testing and verification of methods.

Academical:

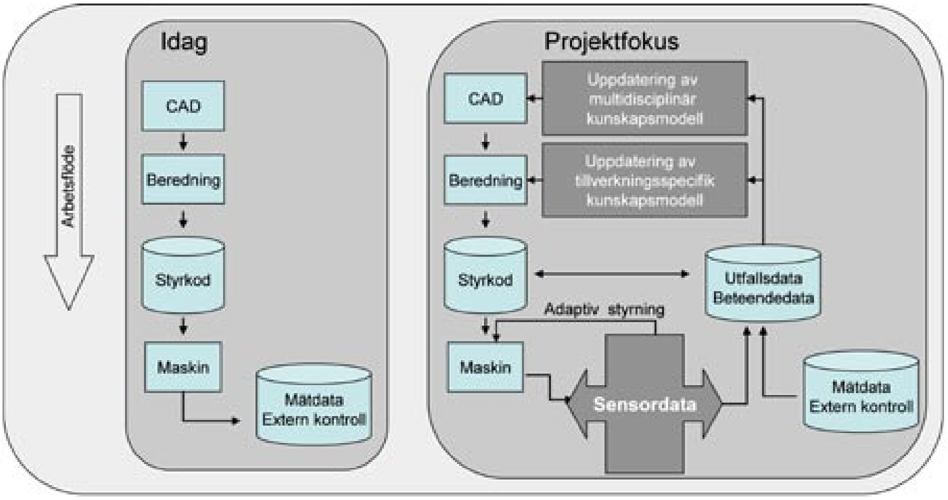
- Two graduate students with the goal to licentiate before the closing of the project has been employed.
- An increased understanding for the natural inertia that exists within bigger companies.

Publications:

- P. Andersson, A.Wolgast and O. Isaksson, "Current industrial practices for reuse of manufacturing experience in a multidisciplinary design perspective", International Design Conference Dubrovnik, 2008
- P. Andersson, O. Isaksson, "Manufacturing system to support design concept and reuse of manufacturing experience", CIRP Tokyo, 2008
- A. Catic, P. Andersson, "Manufacturing experience in a design context enabled by a service oriented PLM architecture", ASME New York, 2008

Project realization

The red line through the DLP-E project is the knowledge based feed back. To learn from our production process. To automate the information feed back, ie a closed loop. See picture below.



Schematic picture of the workflow compared with expected results from DLP-E

This is the third DLP-E project that Volvo Aero is performing. In the previous projects we have set up systems and working methods using the latest technology within the digital world. The latest one is TcM (Teamcenter Manufacturing) from Siemens/UGS. Now we shall strive to combine these systems to achieve full feed back of information. The master data will be controlled hard and only the information needed for each role will be made available for these persons.

The DLP-E project has been divided in three parts/tracks. Status monitoring, Knowledge feed back and MES (Manufacturing Execution System).

- Knowledge feed back from machine, *Status monitoring*, Graduate student from University West, Jari Repo.
- *Knowledge feed back from operator/process (Re-use of Manufacturing Experience)*, Graduate student from University of Luleå, Petter Andersson.
- The work of the two graduate students shall be combined with the *MES solution* that is being set up at Volvo Aero Corporation.

The split up of the project according to above has created a close connection between the industry and the academic world, which has worked well.

The project has been performed in a industrial environment where a so called multi task machine has been used. It is of great interest for the industrial world to be able to verify/validity the possibilities using this type of machine instead of today's production that often use machines specialized in one type of production process.

Project outcomes

- Knowledge gained within MES for Teamcenter and SAP system integration.
- Integration between the systems.
- Evaluation of the "from the shelf solutions" from different MES-suppliers.
- A deeper knowledge about the knowledge based feed back.
- A deeper knowledge about the status monitoring of machines.

Participating parties and Contact person

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The other parties in the project:

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Coor Service AB	Jerker Andersson
Hexagon	Bo Eneholm
Deckel Maho	Göran Bowles
Zooma by Semcon	Anders Björklund
UGS Sverige AB	Lars Sveding
Högskolan Väst	Tomas Beno
Luleå Tekniska Universitet	Tobias Larsson
Kungliga Tekniska Högskolan	Mihai Nicolescu
Nordh Energetic	Anders Nordh

Mod-Fix – Modular fixture content creation

The objective is to develop and introduce new and improved methods and tools for "digital configuration and verification" of manufacturing fixtures for Body in White (BiW) welding and assembly lines. With these methods and tools it will be possible to reduce the present man time and lead time for design and verification of the BiW fixtures.

The objective will be achieved through implementing the latest technology on the marked for robotic simulation and develop new functionality on top of this software platform, together with modularized fixture components, new methods and new roles.

The project will deliver functional software that will be tested in a pilot environment with trained users where the project objectives can be verified.

The pilot environment will after completed project be delivered to the partner universities where it can be used for training and education of scientists, students and other automotive industry.

Objective

The Modfix objectives are:

- To radically improve the IT tools, workflows and roles used today for design and verification of BiW fixtures.
- To create strong and close connections between University and Automotive industry and to provide the academic partners with new and relevant data to be used in training and education.

Results and deliverables

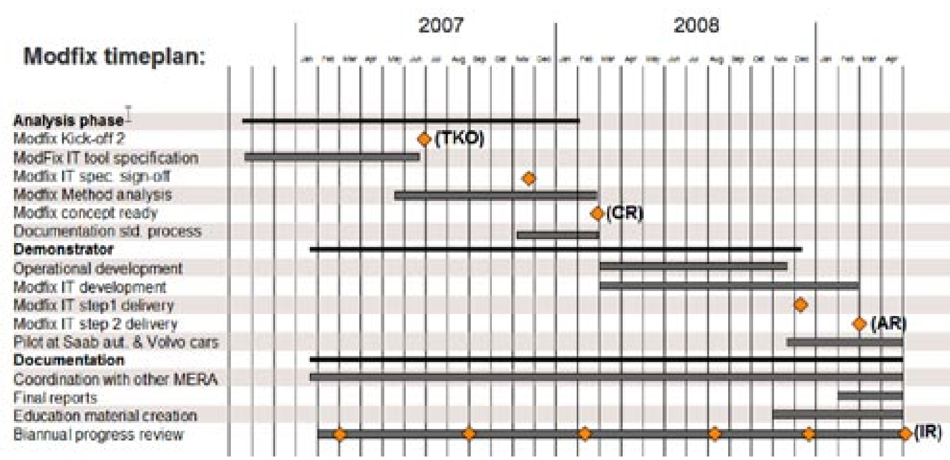
Modfix will deliver:

- New methods and IT tools for BiW fixture design including documentation
- Pilot report Volvo cars
- Pilot report Saab automobile
- Data around design and verification of BiW lines for the academic partners

Project realization

Modfix is divided in three major phases.

- **The Analysis phase**
  - o Business Case Requirements
  - o "As is" and "to be" workflow analysis
- **The Development Phase**
  - o Introduction of software tool
  - o Development of new work methods and work roles
  - o Configuration and setting up of pilot environment
  - o Pilot at Volvo Cars
  - o Pilot at SAAB Automobile
- **The Documentation and dissemination of project results**
  - o Final report
  - o Delivery of project data to academic partners

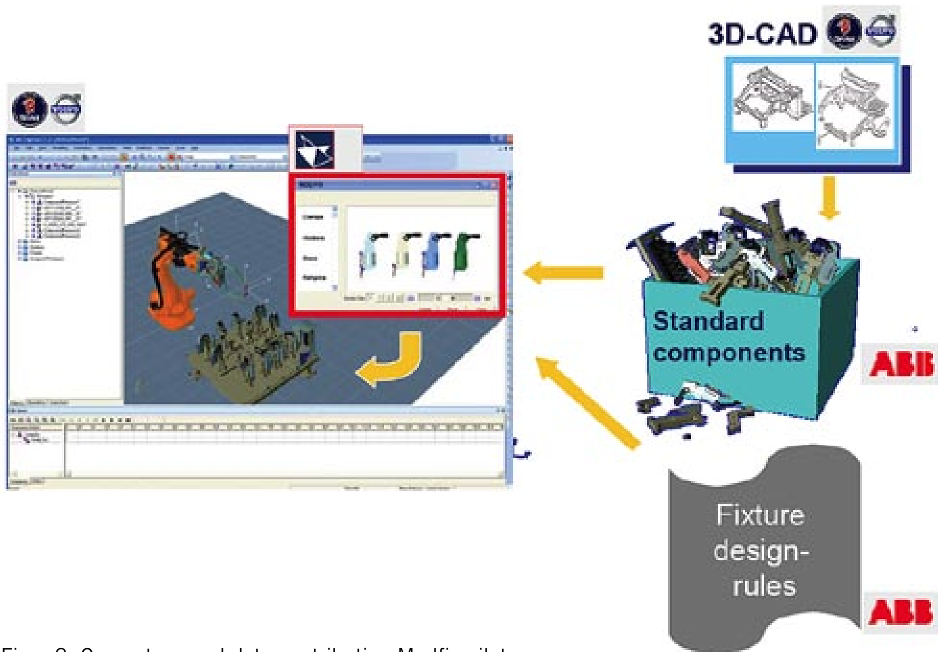


Figur 1: Timeplan Modfix

Project outcomes

Several actors in automotive business are today working more and more with modularized standard components. The Modix approach to use these standard components in the simulation environment and simultaneously design and verify fixtures and tooling equipment will be piloted at Saab and Volvo using the set-up according to below. (See figure 2). However the concept is generic and can later be used by other actors in the automotive industry.

The academic partners will also through the Modfix material have the possibillty to educate other business areas about the benefits of modular design and concurrent tool design and verification.



Figur 2: Competens and data contribution Modfix pilots

Participating parties and Contact person

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Production systems for components

ModArt – Model Driven Parts Manufacturing

The purpose of ModArt is to create an innovative and efficient way of developing production systems for parts manufacturing. It will be a model driven IT-support environment for practical and industrial development. This will be done in a close collaboration between manufacturing industry, academy and IT-companies. Work procedures will be defined and a digital model infrastructure and information platform will be developed. IT-tools from leading vendors will be taken advantage of The main results are Web-based production development manuals that will spread experiences, routines and information in relation to well defined work processes in process planning, factory design, production investments, production and IT-investments.

Objective

There is a great potential to reduce cost, decrease lead times and secure quality by utilizing new development processes for production system development.

The purpose of ModArt is to rationalize the development of production systems by a model driven work processes and methods:

- Coordinated work process and a systematic utilization of IT adapted to the demands from production
- Coordination and reuse of information and models

Results and deliverables

Process models, that describe various activities and their use and creation of information in a synchronized way, have been developed for all areas (process planning, factory design, production investments, production and IT-investments). In these models, the industrial partners of the project have expressed their own working methods, and these methods have been generalized and developed into a model based paradigm.

The process models have been implemented as Pilots for production development, and these pilots will be available in an open version: http://www.produktionslotsen.se, as well as in company specific versions which are configurable according to the specific project models and needs of the companies. The long term goal is to spread and develop the Pilots such that they are useable to other companies in Sweden, this way supporting smaller industrial OEMs and suppliers.

Principles for the communication and coordination of information independent of application and IT-system to achieve interoperability has been developed. ModArt focuses on production information which differs from pure product information. A concept is presented for the modeling and managing of information about resources, processes and products in the manufacturing chain (in-process models) throughout the life cycle of the production system.

The plan is to verify and implement this concept within selected industrial companies in forthcoming projects.

Industrially, the implemented Pilots, and the knowledge of how to realize model driven manufacturing development with the right IT-system for the task at hand are the most important results. Academically, the principles for model driven manufacturing development with the definition of how to structure and model manufacturing domain information and work processes are the most important result.

Project realization

The project is organized as five sub projects for the development of the production development pilots, each describing the digital models and IT-tools for a specific activity, with information shared in a common information infrastructure:

- ABL: Process Planning Pilot
- FPL: Factory Design Pilot
- PIL: Production Investment Pilot
- FBL: Continuous Improvement Pilot
- MIL: Modeling and IT-investment Pilot.

The work was divided into a number of basic work packages:

Study of current industrial manufacturing activities; Study and evaluation of existing methods and tools; Definition of the future model driven work processes; Identification of needs for methods and tools; Development of new methods and tools; Implementation of pilots; Development of integration platform; Education, courses and seminars.

Each of the sub processes address these work packages by studying the activities, developing work flow, studying relevant IT-tools for their purpose together with the IT-suppliers, defining model driven manufacturing and finally implementing pilots and education around it.

ABL – The process-planning pilot

Process planning is a central and complex activity in a producing company. During the activity of planning how a part is to be manufactured, many decisions are made based on experience e.g. concerning the choice of the right type of process, the fixture design, etc. Process planning may also result in the needs for changing the factory layout or investing in new machines.

In ModArt, a process planning work procedure is defined which utilize models of the product and the manufacturing resources and processes.

Models, of parts, tools, machine toos etc. should as far as possible be based on international standards for product data, e.g. feature based process planning, standards for cutting tools and feature based NC-programming.

FPL – Factory Design pilot

To enable a fast design and redesign of the factory, models and experience concerning material flow, layout and installation is required. In FPL, the experience of the participating companies concerning designing and realizing the factory flow and layout is taken care of, and new methods and tools are introduced.

Both new and existing knowledge is documented and formalized using digital modeling, simulation, requirement management and decision support systems, with the results presented in the FPL.

A generic factory design process is defined based on the companies' experiences. Digital models of the factory are used to verify all relevant manufacturing requirements.

PIL – Production Investment Pilot

Investing in large machines often mean a large economic risk, thus the success of new investments is critical to most companies. At the same time the equipment in a factory is often complex, many standards and regulations for e.g. machine security has to be followed, and it is far to easy to make erroneous decisions causing costly redesigns and delays. The purpose with PIL is to support machine investment with a quality secured process that leads to investments that meet the production goals and with decreased lead-time from identified problem to equipment running optimally in operation. A model driven machine investment method is useable for large and smaller companies and various types of equipment. A digital requirement model is developed in steps, based on requirements from process planning and factory design, as well as applicable standards and regulations. The digital requirements are then verified with models of the equipment designs in each step of the work.

FBL – Continuous Improvement Pilot

In FBL, the production operations, control and maintenance are in focus. The major thought is by manufacturing system monitoring and measurements partly improve the manufacturing system and partly provide input for improvement of the earlier processes in the article development. FBL will create opportunities for a focused and resource effective improvement and development work through guiding the user by supplying knowledge and methods in a "do-like-this" manner. The Improvement pilot will contain support that purposes are to define, assess and develop the improvement work. The different parts in the pilot that will be developed are:

- Establish of a local manufacturing standard
- Implementation and development of manufacturing monitoring
- Establishing of Key Performance Indicators
- Establishing and development of improvement groups
- Choice and implementation of improvement methods and tools
- Assessment tool to support a continuous evaluation of the improvement work itself

Furthermore a "vision" will be presented with the latest support methods and tool concerning model driven article manufacturing.

MIL – Modeling and IT-investment Pilot

General issues concerning defining and implementing the model driven activities and pilots are focused in MIL. All pilots are to be based on the same architecture, an architecture that also should support modules for education. While the main goal for MIL is to define the IT-architecture for model driven manufacturing, the modeling and IT-group also provides tools for implementing the other pilots, and identifies common IT-tools within the sub projects.

MIL will be evolving into a tool that supports the investment in IT-systems for model driven parts manufacturing, providing answers to what the requirements are on systems to support a successful model based manufacturing process.

Project outcomes

By using coordinated work processes and up to date information about the resources and processes of the production system, it is possible to achieve the desired capability (ability to manufacture products to the desired quality) and the desired capacity (volume and time) when the system is adapted to new market demands, technical regulations etc. Following are some estimated industrial effects:

1. Time to validate and perform process planning decreases.
2. Time for production ramp up of new products decreases since problems are discovered during digital verification.
   a. Number of scrap when introducing a new product in an existing machine tool decreases.
3. Time for purchase and installation of new machine tools decreases:
   a. Number of unplanned problems with quality, capacity and cost reduced since problems are discovered at digital verification.
   b. Time for adjustments after installation (ramp up) decreases.
   c. Total cost of investment in the production system decreases
4. Productivity increases since processes and resources can be optimized

For more information, please don´t hesitate to get in touch with the concept persons, or visit: http://dmms.iip.kth.se/current-programs/modart (DMMS portal)
http://www.kth.se/itm/inst/iip/forskning/dkt/2.1045 (Portal for KTH – School of Industrial technology and Management) and, from early 2009:
http://www.produktionslotsen.se

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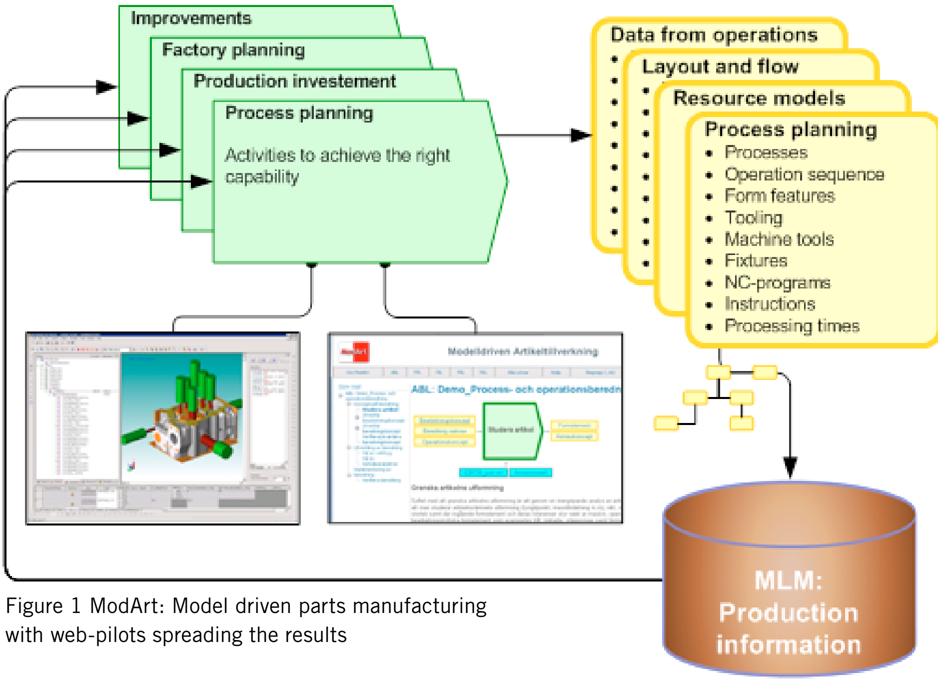
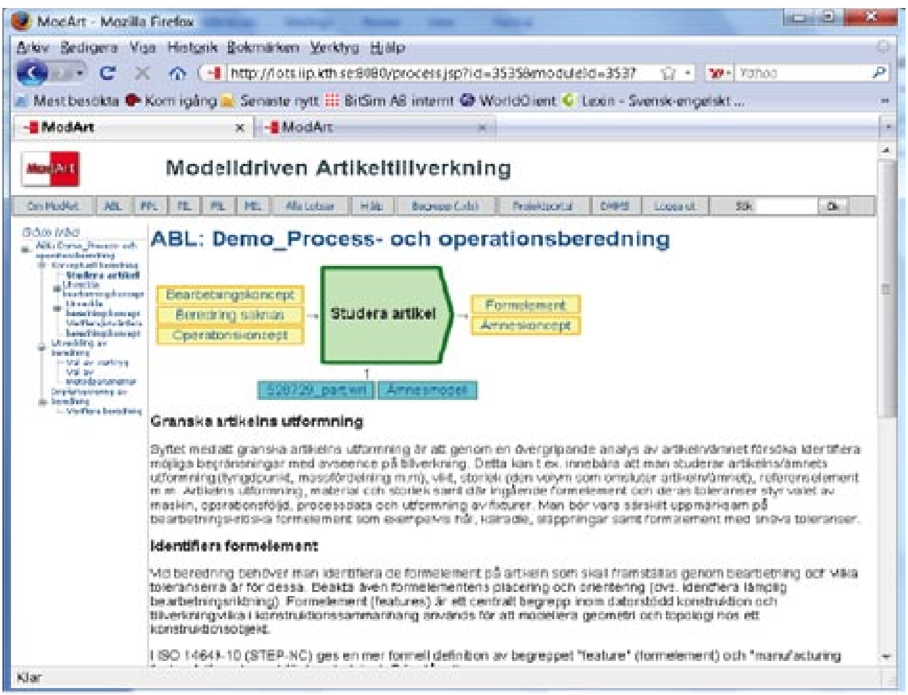


Figure 1 ModArt: Model driven parts manufacturing with web-pilots spreading the results



Example of interface from one of the Pilots: Process planning pilot, ABL

Simulating out of roundness for cast components

The main part of this project concerns simulation of out of roundness of cylinders in engine blocks made of aluminium with cast-in grey iron liners. To validate models, and serve as experimental evidence, measurements have been done on blocks in between boring operations in the cylinders, i.e. the blocks were taken off the production line, measured and reinserted until the next boring operation was done, then taken out again and re-measured.

The out of roundness after cooling of the cylinders was correctly predicted at the top of the block, but some deviation existed in the lower part of the cylinders. There were uncertainties about how well the used material models described the real material behaviour and it was therefore decided to perform material testing of aluminium specimens taken from around the cylinders and calibrate those to two different material models. This was done within a diploma thesis. The testing showed that the material exhibits pure elastic-plastic behaviour up to 200°C. Above 200°C the rate-dependence increases fast with increasing temperature. The material models used to capture this behaviour were one Perzyna model and one model already available in ABAQUS-standard called the Two-layer viscoplasticity model. As it turned out the latter model was the one best describing the material behaviour. This new material model was then used to perform new simulations. Also with this new model there is a difference between measured and computed out of roundness in the lower half of the cylinders. Simulations have been made describing different cooling rates and some small modifications in the FE-model has been made with very small influence on the results.

The next step was to simulate different manufacturing sequences. Two different sequences were compared. In the first, the cylinders were processed in two equal steps. In the other sequence 80 % of the material was removed in the first step and the rest in a second step. These simulations indicated that it is preferable to begin with large step and finish with small one to minimize the remaining distortions. It was also suggested that water slots between the cylinders which are today machined after the first boring operations in the cylinders, should instead be machined before the first boring operation in the cylinders.

Objective

The aim of this of the project is to study the out of roundness in the cylinders in a Volvo 5-cylinder gasoline engine. With knowledge about the behaviour of the engine blocks during the cooling after the die-cast process, and during the different manufacturing steps, we will be able to predict distorsions in order to improve the manufacturing process, and in that way reduce production costs. In the drilling process of the engine blocks problems with out of roundness occur in the cylinders due to built up stresses from the casting process. First two cylinders are processed simultaneously with good results. Thereafter, when the next two cylinders are processed the problems occur in the first two cylinders. To make the manufacturing process more efficient, better knowledge of the out of roundness development is needed to be able to make better decisions concerning e.g. the sequences of the machining steps. The idea is that this can be accomplished via the development of a Finite Element model that can simulate the distortions occurring in the cylinders during machining. When it's possible to predict these distortions different manufacturing sequences could be simulated and the production can hopefully become more efficient.

Results and deliverables

We summarize the final part of the project as follows:

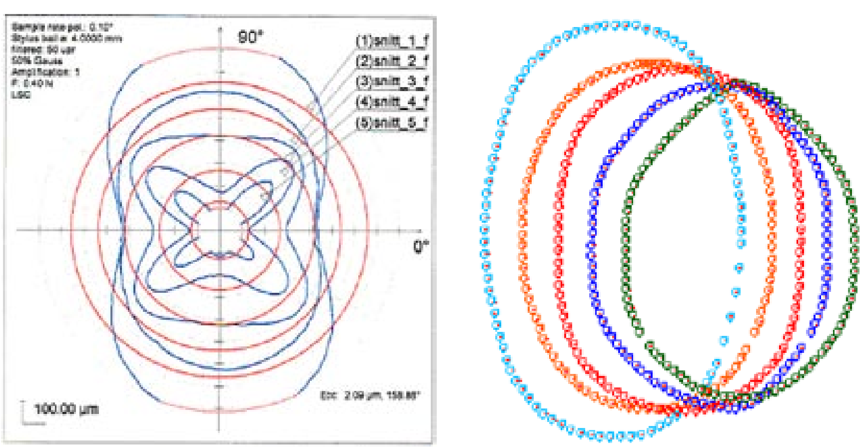
- The new material models did not alter the results. Both the out of roundness shape and the stress & strain distribution are very similar to before.
- The simulations with different heat transfer coefficients for different cooling rates also shows that these effects are of neglectable importance.
- A simulation where a certain slip in the contact surface between liner and block is allowed has not been made. However out of roundness measurements of another type of block that has a bonding in this interface that is well represented by the "TIED-contact" used in the simulations became available after completion of the project and showed no deviation compared to previous measurements. It can thus be assumed that the contact condition used ("TIED") well represents the actual conditions.
- When it comes to the manufacturing sequences it is noted that the stress relaxation is directly proportional to the removed material volumes. This means that the bigger volume removed the bigger shape deviation throughout the cylinders. Since the drill compensates for deviations in previous steps it is therefore proposed to finish with small steps. To exclude the effects from when the water slots is being processed they should be processed in a separate step before processing the liners.

For future investigations it is a recommendation to more thoroughly investigate the residual stresses with measurements and corresponding simulations. It should also be of importance to come up with ways of how to further improve the FE-model. To be sure that the contact definition well represent reality, a validating simulation is preferably performed.

Project realization

The project has been carried out, basically, in different steps according to:

- Modeling and numerical simulation of the thermal cooling of the engine blocks right after the high pressure die casting.
- Modeling and computation of residual stresses in the engine blocks. This process consists of the steps
  - Preliminary modeling using non-linear creep models with non-calibrated diagnosed material parameters.
  - Mechanical testing of the aluminium material in order to achieve a better material model for the proper description of the viscous behavior of the aluminium. (This work was done a master thesis work.) The work here involved tensile testing of aluminium specimen taken from around the cylinders in the engine block at various temperatures and strain rates. These tests are then to be calibrated and evaluated with respect to two viscoplastic material models.
  - Modeling and computation of the residual stresses. A fully 3D block model of the engine was used.
- On the basis of the residual stress state obtained, a simplified analysis of final machining process was made, via element removal technology and the simul-



Out of roundness. Measurement (left) simulations (right) taneous analysis of the obtained out-of-roundness of the liners embedded in the block. Validation of the modeling results was made with respect to physical observation/measurements of the out-of-roundness. Reasonable agreement was obtained between the modeling and the observations. In particular at top of the cylinder liners, as shown in the Figure below.

Project outcomes

- Developed thermal and mechanical modeling procedure for the analysis of residual stresses and out-of-roundness deformation in liners of engine blocks made of aluminium.
    - o Results obtained for the prediction of residual stresses, due to the high-pressure die casting manufacturing process, of engine blocks both before and after the final machining process.
    - o Validated results obtained for the out-of-roundedness with respect to a predefined machining sequence of the engine block itself and the embedded liners.
- The obvious potential use of the project is to exploit the proposed procedure to predict out-of-roundness for alternative machining sequences of the engine blocks. Thereby, a scientific based methodology is devised to optimize machining sequences in the discussed context.
- Finally, we emphasize, apart from the technical and scientific achievements of the project, we have reached the goal of establishing a well functioning network of competence. Both we here in the "academy", involving researchers from two different departments here at Chalmers, and the involved people from different departments on the industrial side have experienced invaluable contacts in the network. Thus, on the basis of the established network, we look forward to new challenges in research and cooperation related to our common interests.

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Generation of handbook for steel and heat treatment

A new handbook for heat treatment of steel will be generated. Today there is no up-to-date handbook in this area in Sweden. In the handbook existing competence will be collected and taken care of. The book will be used for education and continuous improvement of competence at companies and for students at universities.

The book will be available both on the webb as well as a physical book. It will be written in Swedish, but after the project the intention is to also have it translated into English.

Värmebehandlingscentrum (the Swedish Heat Treatment Centre) has initiated the project.

Objective

To collect and take care of existing competence within heat treatment by generating a handbook for steel and heat treatment. To provide knowledge of heat treatment to companies and students.

Results and deliverables

The project has started during autumn 2008.

Project realization

The members of the Swedish Heat Treatment Centre, the companies and the institutes, will be main performers, but also other companies and organisations will be invited to participate.

Two main editors and an editorial committee will be chosen. The work will be divided into sub-areas with working groups and a manager. The working groups will function as initial auditors for respective area.

The final content of the book is not yet established, but the following headlines are suggested:

- Basics of metallurgy
- Material testing
- Steel and alloying elements
- Hardenability

- Basics of heat treatment
- Heat Treatment Processes
- Pre- and post-processes
- Distortions
- Product characteristics after heat treatment
- Simulation of heat treatment
- Quality aspects
- Construction aspects

Project outcomes

The handbook will be public. It will work as schoolbook as well as reference book for companies and students.

Participating parties and Contact person

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Bodycote Värmebehandling AB
EFD Induction AB
Finnveden Powertrain AB
Ovako Steel AB
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MERA conference 2008

Production systems for sheet metal workshops

KOMPROD

The aim of the project was competence development in a Supplier Network specialised in design and production of advanced products in high-strength steel. The project has focussed on advanced stainless steel with high strength.

Objective

In order to breach the gap between theoretical research and applied methods within the production industry, this project was initiated to increase the competence in Swedish supplier companies. The main objective was to develop theoretical knowledge and practical experience within design and production of vehicle components in high strength steel.

Results and deliverables

The project result was a network of competence consisting of suppliers and R&D partners with special expertise in developing and producing high-strength components. The objective was to stay competitive in an international perspective, and to be qualified to modify existing production methods in order to optimize the productivity of high-strength steel product manufacturing.

Another deliverable was development and analysis of production processes suitable for stainless steel with a high tendency of deformation hardening. Demonstrators were used to test these production methods and the new demands on the design process.

Project realization

A Swedish supplier network with focus on automotive suppliers was created within the project. The network companies developed and participated in workshops and lectures in collaboration with researchers from University and Institute. The scope of the seminars was to increase the knowledge and experience of design and production of automotive components in advanced high strength steels developed by Swedish materials suppliers. The seminars were designed to function as a generic model generating practical knowledge needed for the industrial implementation of new steel materials. The efficiency of the model was evaluated within the project.

Industrial demonstrators were used as practical case studies to increase the skill in adapting a current product into a high-strength alternative.

A chosen number of production methods suitable for high strength stainless steel were further developed from theory to practice using experimental evaluation and FE-analyses.

Project outcomes

Network of competence

Four two-day Workshops have been performed, with the main topics: Stainless materials, Design and FE-analysis, Production Methods and Materials Utilization. An active network has been formed as a consequence of these Workshops, and the network has cooperated in an open-minded spirit. The supplier companies have shared their experience and niche expertise within production of high-strength components, and some partners have continued the collaboration in new R&D projects. The good collaboration climate has also been of importance for the production of demonstrator prototypes.

Demonstrators

An industrial project leader in cooperation with one project leader from Swerea IVF or Outokumpu Stainless coordinated the industrial demonstrators.

So far, three demonstrators have been developed into prototypes:

1. Bike carrier: Industrial project leader: Heléns in cooperation with Thule. High-strength stainless tubes were stretched to high strength and ovalised before bending in order to replace the tubular parts of the carrier.

2. Corner Steadies for Caravans: Industrial project leader: Samhall. A modification of the design and prototype development in a high-strength stainless steel has been evaluated by numerical methods and experimental tests.

3. Fuel tube: Industrial project leader: Autotube. A fuel tube sealing has been formed in high temperature, and has been evaluated with respect to vibration fatigue.

Process development

Tube stretching:

By uniaxial stretching, tubes from unstable austenitic stainless steel can increase in strength by deformation hardening to martensite. In order to develop rules for needed initial tube dimensions before stretching, FE-analysis can be a method to evaluate possible tolerances for standardised final tube dimensions.

The process of tube stretching to high strength has been developed experimentally, but earlier studies using FE-analysis showed poor correlation between the numerical predictions and the experimental results. In this project, further analytical studies pointed to the need for new materials data, involving tensile testing at high strain rates. Experiments with tube stretching under different conditions coupled to tensile testing of sheet metal have been performed and compared to analytical calculations and FE analysis. It was shown that the diameter and tube gauge could be predicted with good tolerances if effects of strain-dependent R-value were included.

Stretch blank forming:

Pre-stretching of sheet metal blanks to increase the materials utilization was investigated experimentally. The process was abandoned based on the experimental results, as not enough material was saved.

Increasing the strength of welded joints:

Stretching to high strength and butt-welding was used to produce tube samples. As the welds have a lower initial strength than the welded high-strength steel, stretching the welds to a higher strength was evaluated. The resulting strength of the welds was measured by tensile testing. The results were positive as the welds increased to a strength matching the tube strength.

Demonstrators in original materials: a) Bike Carrier, b) Corner Steady for caravans.

Workshop # 4: Materials utilization and demonstrators.

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Production processes for body in white (BIW) of mixed lightweight materials

The use of mixed lightweight materials for BIW production in the automotive industry is set to increase. These materials ensure better crashworthiness/safety performance and/or reduced weight, but do not impair strength. Reduced weight lowers the environmental impact and offers better fuel economy. The project is aimed at increasing knowledge in the BIW production processes employing mixed lightweight materials.

Purpose

The project code-named "Production processes for BIW of mixed lightweight materials" has been initiated at GME (GM Europe) as part of meeting the requirements set for the Saab brand as regards product cost and flexibility of production systems, while observing the requirements on safety, fuel consumption, etc.

The production processes that are currently included in the project shall be based on the GME "Mixed materials'" strategy. These will contribute to strengthening the Swedish automotive industry through increased flexibility and shortening of the production time of a BIW of new lightweight materials that contribute to reducing the car weight.

In the short term, to increase the possibility of achieving competitively the knowledge-based development and production of lightweight vehicles through assuring and strengthening the competence at GME - THN. In the long term, to develop and strengthen the collaboration between GME – THN, researchers in the academia and other parties in the MERA programme.

The project results shall lead to a "Center of excellence" in Trollhättan, Sweden, with knowledge of and competence in manufacturing vehicle bodies of mixed lightweight materials. The Project shall also lead to a stronger and more effective cooperation between the automotive industry and academic institutes in Sweden. In long term, this will secure competence and act as a strong reason for future competence-based production in Sweden. Also to establish a "Centre for the Development of Convertibles in Trollhättan". The orientation on niche cars and convertibles requires the production process to be adapted to shorter production runs, with more variants of each model.

Results and project implementation

The project is divided into four sub-projects:

A) Production process
B) Development of forming and joining processes
C) Digital support for process development
D) Adaptation of the production process to market requirements

A) Production process

Sub-project A1: Process development for small cars made of mixed lightweight materials. The concept phase has resulted in several lightweight material designs, including how these materials will be joined in the BIW process. The modularization work is done in a Sedan / Convertible simulation model. Two suppliers, Gestamp HardTech and Outokumpu, have participated in the production and adaptation of all parts. Calculation work has been completed and all parts have been adapted for production. One virtual concept has been presented internally at GM, where the weight and cost were found to meet the requirements.

Sub-project A2: Modularized structure for niche cars. This has shown that it is possible to save approximately 50 kg on a convertible structure when consideration is given to the common interface in the design, and the bodywork process is adapted accordingly in the production of new platforms (including the production process).

Sub-project A3: Process development for modular rear floor. Offers great scope for adapting the rear floor to customer requirement in the same production equipment, without compromising on the product requirements, through a modularized structure.

Sub-project A4: Low-cost joining process for lightweight doors. Modularized approach has also cut production costs. The introduction of new UHSS materials has necessitated a change in process parameters in order to find optimum welding windows. This has provided the possibility of producing a new door structure with lower weight, fewer components, lower cost and simplified production

Sub-project A5: Modular doors of mixed lightweight materials. The result shows that the combination of UHSS and aluminium is most cost-effective for minimizing weight. Modular construction doors that can be used for several different models (brands) using the same production process have become "mainstream" at GM. The virtual solution gave very promising results for the future in terms of lower weight and cost and shorter manufacturing times in production.

B) Development of forming and joining processes

Sub-project B1: Joining an aluminium front to a steel structure. The project is aimed at saving weight, particularly at the front, since high-performance premium cars tend to be heavy at the front, which impairs road behaviour. It is then important to make the front structure of lightweight materials. An aluminium front structure has been developed in order to save weight at the front end and thereby improve the road behaviour of the car. The aluminium front is joined to the remainder of the steel body in a cost-effective manner by using a joining process that has been verified to provide an aluminium/steel joint while maintaining the product requirements. Since spot welding causes serious problems, riveting and adhesive bonding will be used, with proven process windows that safeguard the quality of Saab cars. Prototype parts have been produced jointly at Saab and Hydro, and complete front structures have been produced at Saab. Prototype cars have been built at GM Canada during the spring and summer of 2008, and testing will be carried out in the autumn of 2008, including crash, corrosion, fatigue, etc. in order to safeguard product requirements, verify the simulations, and validate the production process in the factory (at Lansing in the USA). The cars will be built in the USA/Canada.

Sub-project B2: Process for strengthened body structure with lightweight materials, incl. joining possibilities. Another important result is the way in which various strengthening materials are implemented, such as aluminium/foam, plastics, composites, etc. in order to strengthen thin-wall beam sections or as local reinforcements at mounting points, etc. in the body. A problem is to find a process that allows plastic foam, for instance, to be used without negative impact on the working environment. The project has delivered a theoretical study of the materials available on the market, which has been compiled in a report that includes: cost, weight, material properties, hygienic risks, process facilities, etc. The report also includes the results of simulations of important properties, such as stiffness, safety, sound emission and process parameters.

Sub-project B3: Joining process for sandwich materials in body parts. The project has studied the new lightweight solutions for recreating sound performance, NVH (to at least today's level), at a low cost and without affecting the production process.

Benchmarking and simulations have been carried out highly successfully. Concept selection has been carried out for roof sheet, aluminium front structures, etc. Tests were carried out on mules in order to correlate the simulation work.

Sub-project B4: Joining of body parts of roll-formed material.Resulted in an understanding of how welded components of boron steel should be designed inorder to make strong welds, and how the direction of rolling of the billets affects cracking whensubjected to dynamic stresses.

C) Digital support for process development

Sub-project C1: Optimized production processes for high strength stainless steels. Material properties and material models for CAE codes have been produced and a virtual demonstrator in the form of a B-pillar for the Volvo S40 has been developed. The results in the form of hardware are crash-tested B-pillar that have been shown at all participating OEMs and also to other project participants. Information on the project results has been launched by visits to all participating companies, and this "Stainless Steel Academy" will be rolled out during the whole of 2008. Work has been started on Block 3, i.e. the virtual design of a platform made entirely of stainless steel, with the aim of demonstrating the results in the form of Weight/Cost/Performance at the Motor Show in Frankfurt in Sept. 2009. The reference in Block 3 is the GM Kappa platform. Will be concluded at GME in Dec. 2008.

D) Adaptation of the production process to market requirements

Sub-project D1: Towing concept specified by Marketing. A new demand from Marketing is that the tow hitch of the future should be controllable from inside the car. The concept was shown to be too expensive, which is why this resulted in being quite an ordinary concept that does not increase the production process costs, while still meeting the normal usability requirements of the markets.

Sub-project D2: RHT – Removable hard tops for convertibles. Saab wants to retain its leading role at GM and to build up a knowledge base in a centre for the development of convertibles, with the aim of moving production to Trollhättan. SAAB traditionally had "soft tops". Work in the sub-project has therefore been concluded with a study of how our production process could be adapted to all types of convertible in the same production line in Trollhättan.

Project outcomes

The project has improved the possibility of achieving competitively knowledge-based development and production of lightweight vehicles by developing and strengthening the know how at GME - THN. A product process will be developed and verified both virtually and physically. The results will lead to the implementation of a flexible production system for future car ranges / models in the whole of GM. The expected effects are fewer physical prototypes, faster ramp-up at the beginning of production, fewer production stoppages, lower material consumption, and a product that strengthens the Saab brand in the market. Furthermore, the "Centre of Expertise for Convertibles" has become reality and, in the future, this will be an important part of retaining production of niche cars in Sweden.

The Stainless Steel Academy will continue to be held in the future at regular intervals at all participating companies. All materials and results from this project will be stored in joint GM databases and may be used in future car projects.

Participating parties and Contact person

Project parties:

Saab Automobile AB	Lars-Olof Hellgren (Project Leader)
Innovatum AB	Lillemor Lindberg

Participating suppliers:
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Virtual Paint

Methods and IT-tool for simulation of spray painting, both pneumatic and electrostatic, with a performance to support interactive product feedback. The project also handles the processes for extruded material such as Sealant and Glue.

Objective

The main project goals are:

1) Exclude on-line activities in production for product change-over
2) Reduce waste due to inefficient overspray.
3) Exclude expensive technicum trail to introduce new car models.
4) Increase product quality.
5) Reduction of cycle time.
6) Faster plant introduction times for new products.
7) Build up of a strategic research and development group in virtual paint.

Results and deliverables

The result will be implemented in a IPS Spray demonstrator with the capability to simulate paint thickness almost in real time. The simulation is based on paint process data such as paint flow and bell rotation speed, product geometry and paint stroke motions. The result is the air flow, the electro dynamic effect and where paint particles hit the curved geometry. The thickness prediction has been successfully verified with experiments.

This project includes development and new technologies like:

- Unstructured finite volume numerics based on the SIMPLEC algorithm has been developed for solving the fluid flow
- Electromagnetic field is solved on the same unstructured mesh as the flow field, with boundary conditions and charge distribution from momentary spatial distribution of charged particles as input
- Droplet tracing, where the droplets are located in the mesh using a binary tree search algorithm, and then tracked in an efficient manner through the flow field
- Advanced experiments and validation using Particle Image Velocimetry techniques

Project realization

In this project we have build up unique competence around how to simulate paint processes, this due to the fact that the process experts from the automotive industry has worked side-by-side with the mathematical experts of Fraunhofer Chalmers Centre.

Project outcomes

A method implemented in the IPS-toolset for simulation of spray painting for both pneumatic and electrostatic painting which is at least 1000x faster then any commercial available solver.

The application can also simulate the process for extruded materials such as sealant and glue.

These innovations will lead to reduced material waste, reduced lead time and effort when introducing a new product in a paint process and higher quality for the end customer.

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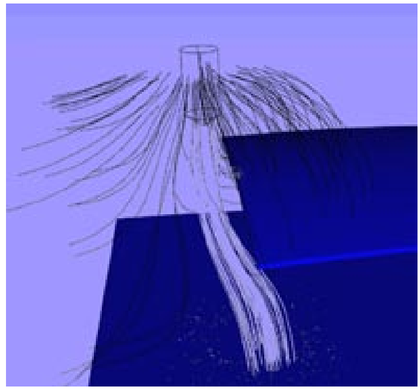
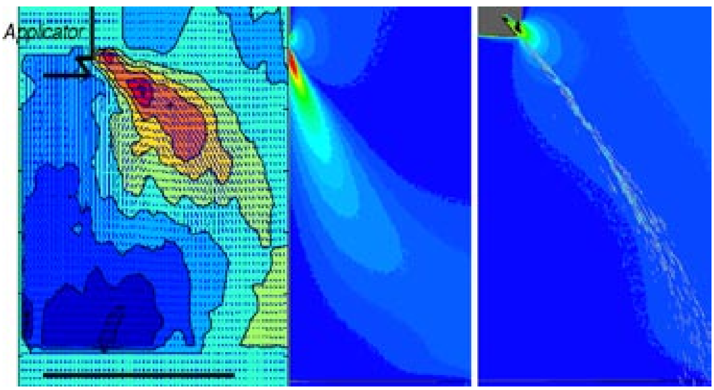
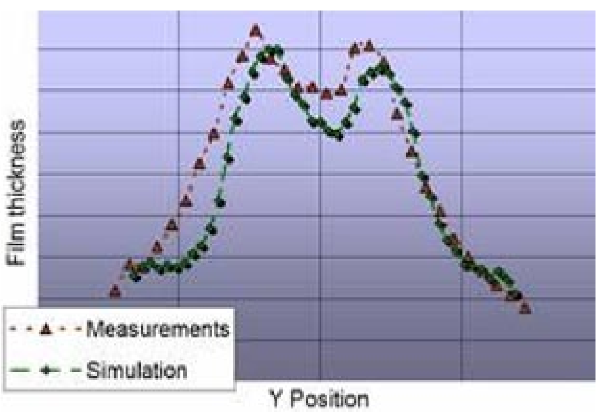
Robotized painting at Volvo Car



Paint simulation in IPS



Experimental and simulated data on particle velocities



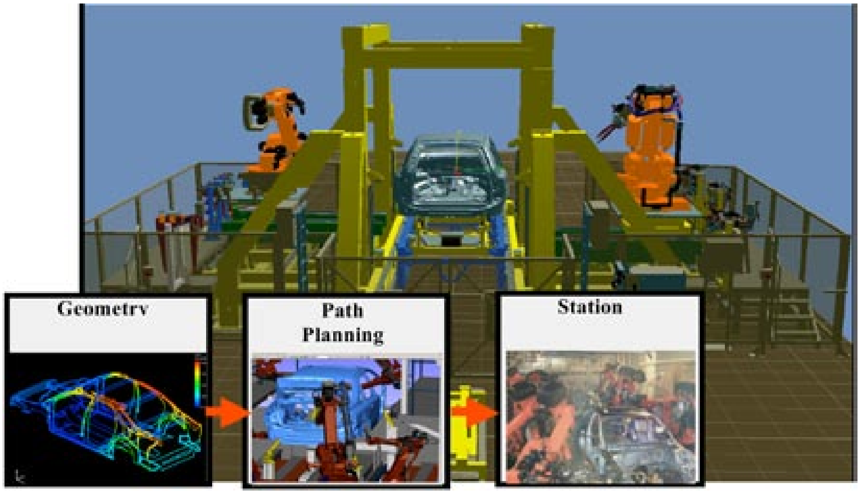
Paint thickness profile validation

Geometry Assurance Path Planning and Station Logics

Geometrical variation, originating from individual manufacturing and assembly processes, often propagates and accumulates during production, resulting in non-nominal products and production equipment. Geometrical quality problems are often discovered during preproduction or when the product is getting ready for market introduction. A change in the product or production concept at this stage often result in huge costs for product and/or production changes, market delays and bad publicity.

A long term vision within the field of production technology is the virtual factory, with high level of accuracy regarding realism and functionality. Early programming, simulation, verification, and visualization of virtual production equipment make it possible to reduce the ramp up time in the real factory. Most programming of motions and paths for robots and equipment is still generated manually, since the existing support for automatic path planning and line balancing is very limited.

Today, geometry assurance, robot path planning and line balancing are carried out partly manually and isolated with limited transparency. Therefore, this project integrates variation simulation, pathplanning, sequencing and line balancing with station logic to generate an integrated and costeffective manufacturing process where product quality and cycle time can be evaluated and optimized for different product and production systems. To successfully meet future demands, research within each of the three focus areas is necessary.



Objective

The goal of the project is 25 % increased productivity in the manufacturing system and a more cost effective product development process. Deliverables are methods and tools for:

- evaluation of different welding strategies with respect to geometrical quality
- optimization of assembly paths with respect to geometrical variation
- general algorithms for sequencing and load balancing of operations
- optimization of cycle time and plant throughput
- trade-off analysis, for different welding strategies, between quality and time
- automatic generation of robot programs for optimal trade-off between quality and time
- coordination and optimization of multi robot cells automatic generation of PLC control code for station logics in a virtual environment, based on product and process information.
- verification of larger PLC programs by formal methods
- physical demonstrator for knowledge transfer
- industrial PhD students
- global strengthening of Sweden as a research nation All results are generic, i.e. can be used by all automated industry.

Results and deliverables

Project results will be implemented as tools and working procedures within collaborating companies but also spread outside the project. A demonstrator will be developed to demonstrate the basic concept and to highlight project results. The demonstrator will be used for knowledge transfer and education and can also serve as a platform for further research within cost-effective product realization.

In parallel with this project, a Ph. D Candidate will conduct research concerning the interfaces/negotiations between ***Path Planning and Line Balancing*** and the two other technologies: **Geometry Assurance and Robot & Station Logics.**

Project realization

This project is collaboration between the Wingquist Laboratory, the Fraunhofer-Chalmers Centre. Three scientific and industrial areas; geometry assurance, path planning & line balancing and robot & station logic are here combined to create a cost-effective product realization process. The project hereby integrates variation simulation, path-planning, sequencing and load balancing with station logic.

Project outcomes

All results are generic, i.e. can be used by all automated industry.
See above objectives.

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Production efficient N&V-treatment of car bodies – Sprayable sound deadening

The Project has evaluated the potential of replacing, the in car industry, manually placed traditional damping pads with sprayable alternative.

Objective

The objective of the project has been to strengthen the competence and development level of SAAB Automobile AB to world class within sprayable sound deadening. This means that Saab Automobile could take the lead within GME for the area. Furthermore the process equipment supplier Teamster AB, which participated in the project development process, would be certified for delivering process equipment to GM world-wide. Finally a part of the research should be carried out as a Master of Science Thesis

Result and deliverables

The project has made studies to determine when and how sprayable damping can be performed, but above all to make the vehicle production more efficient.

The result has lead to development of and more knowledge in:

- A more flexible production system – Sound damping according to the car specification, for instance more damping on cars with diesel engines.
- How to make sound damping with lower weight or how to improve damping with same weight.
- A production system suitable for a large volume but composed of multiple low volume variants.
- Decreasing total process time, time/car.

Furthermore SAAB automobiles competence within this area has been improved and SAAB Automobiles competitiveness within GM has been strengthened.

Project realization

The project has tried to analyze all aspects to reach the target – effective sound deadening of car bodies. The main part of the work has been on process and process selection.

1. Material evaluation

The first step in developing an effective process was to select suitable materials – the selection included both types available in Europe, but also material types used outside Europe.

The objective was to select a variant representing existing material types and one that could bring material- and process technology forward.

The evaluation was performed in a lab environment. First the sound deadening properties were investigated, as well as other product characteristics, and finally the process capability for a limited number of sprayable materials.

2. Application study and optimization.

The second step in the project was to verify sound and other product characteristics in a full scale test, as to certain characteristics are exhibited only in a full scale car test. The test was executed on 3 car bodies, one with epoxy, one with waterborne acrylic and one with the bitumen pads of today.

The Optimization was done in a number of steps with acoustic measurements in between. The damping measurements were done in a small-meshed net and for every measuring point a result was recorded, see fig. 1. The target, among others, was to minimize the amount of material to save final production cost, the weight saving achieved was up to 18 %.

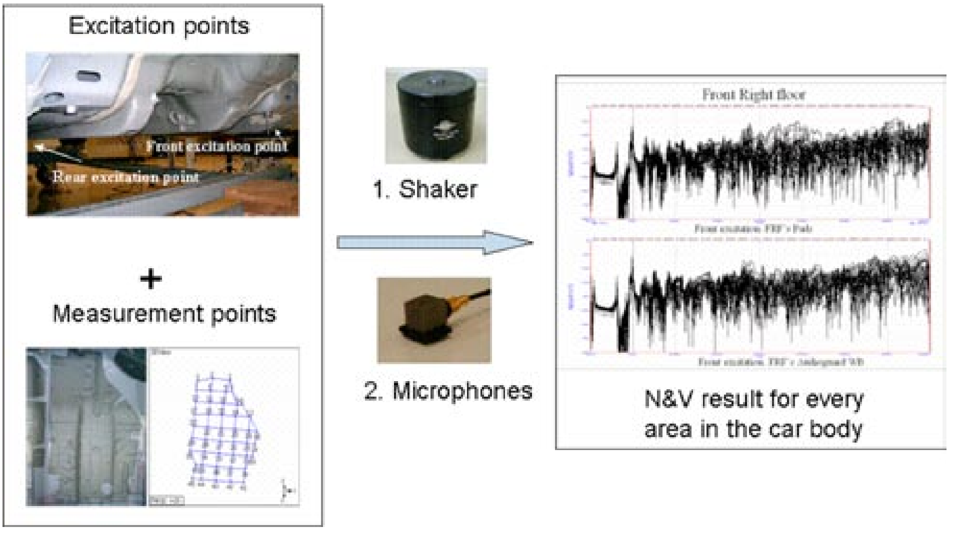

Fig.1. Sound deadening measurement of car bodies.

N&V-evaluation on complete assembled vehicle;

The 3 car bodies where assembled to full vehicles in the normal process. These were also evaluated in a number of measuring points.

3. Process and process selection

The main target regarding the process study was to make a comparison between existing material and sprayable alternative. Evaluation of process risks and suggestions for possible countermeasures where made within the areas below;

- Quality and capability for the material application
- Indirect influence on quality
- Health and safety risks for production personnel.
- Process availability and maintenance issues.
- Ability to spray/ application equipment and nozzles

The evaluation was made at a number of relevant areas, see fig.2 below.

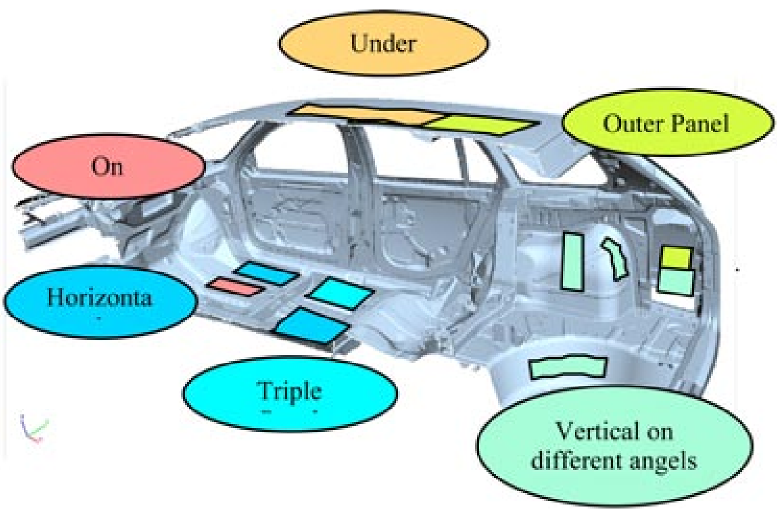

Fig. 2. Evaluation of sprayable material on different surfaces.

One conclusion from the evaluation is that epoxy material used on the European market could not be used on the inside of skin panels (outer panels) because of the read through effect. See fig. 4 below.

Similar phenomena could not be observed when waterborne acrylic material was used.

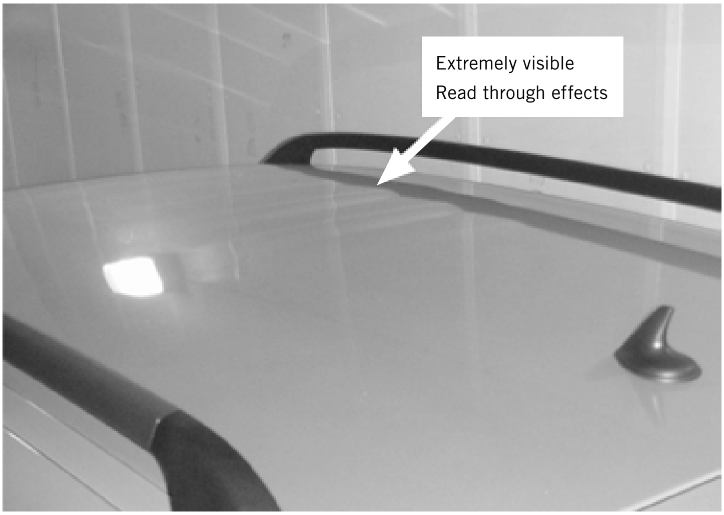

Fig. 4. Example on surface disturbance (Epoxy at minus 20 °C.)

Project Outcomes

Based on the project evaluation regarding sound deadening characteristics, usability in the manufacturing and economy, the conclusion is that the spraying technology and the waterborne acrylic based material, is an obvious alternative to the Pads of today.

In fig. 4, the evaluation of the material types is shown. In the table one can clearly see that waterborne technology is prefered. Specially when damping property, the effect of the material on skin panels (read through), smell in car – and EVAP (evaporation of hydrocarbons) is regarded.

Summary	Pads	LASD	
	Bitumen pads	Acrylic based (Waterborne)	Epoxy based
Damping properties, oberst	2	2	1
Damping on car same weight	2	3	2
Full contact damping material to panel	2	3	3
Read through	3	3	0
Odour in car	3	3	1
EVAP	2-3	3	1
Cracks & lose mtrl	2	2	3
Flexibility to model changes	2	3	3
Product weight	2	3	2-3

3 GOOD 2 OK 1 POOR 0 NOK

Fig.4. Evaluation of the two material types examined – compared with the present bitumen pads based on lab- and process investigations.

In parallel with the development of material- and application method development a logistic investigation "Introducing Additional Car Body Variants" has been made concerning the possibility of introducing variant specific sound deadening.

The investigation has been made as a Master of Science Thesis by 2 students from Chalmers University of technology. The result shows the consequence of connecting a certain applied amount of material to car engine type already in the Paint shop. As a bonus the analysis has also given the company some other ideas of rationalization possibilities.

The project has resulted in that R&D personnel at Saab Automobile AB in Trollhättan and Teamster AB in Brålanda have developed their competence regarding different materials sound- and process properties and their interacting with process equipment. Teamster AB has during the project also been certified as a process equipment supplier to GM world wide.

The project's purpose and objective have been achieved. Fig. 5 shows a sum up for the entire project – a comparison between today's material bitumen pads, with waterborne material and epoxy material.

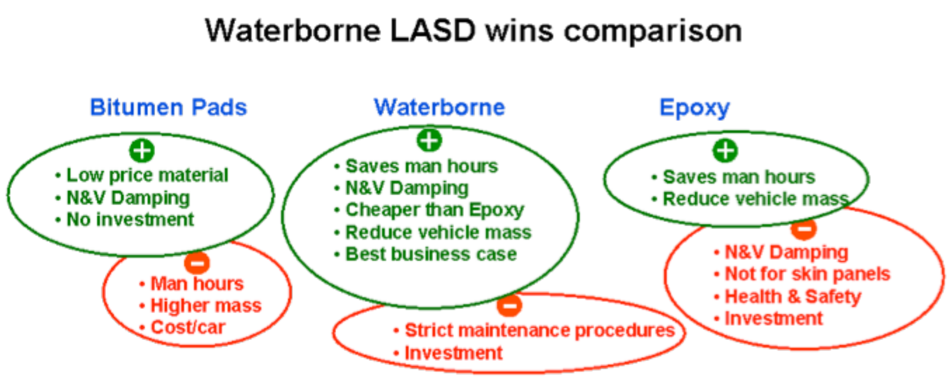

Fig.5. Overview of investigated technologies.

Participating parties and Contact person

The project have been a co-operation between Saab Automobile AB and Teamster AB

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Feasibility study on closed loop phosphate pre-treatment

Within the vehicle manufacturing industry pre-treatment before painting stands for the single largest consumption of water constituting about 70 % of the total consumption (of the factory). In fact, only about 30 % of the phosphate pre-treatment chemicals are utilised, i.e. will form the coating on the body and cabin. The rest is spillage. The objective of the project is to recover most of the water and chemicals, which today is spillage. This must be possible to accomplish without lowering the standard of quality.

Objective (Aim)

The aim of the project is to evaluate and further develop the technology for recovery of water to the rinsing bath and chemicals to the phosphate pre-treatment bath from the zinc phosphating process without lowering the standard of quality.

Results and deliverables (Objectives)

The effects pursued in the project are to make the industrial partners decide to implement a recovery system, which will reduce the consumption of fresh water by 90 %, reduce the amount of waste water by at least 95 % and waste heavy metals by at least 80 %, achieve an equal or improved quality of the phosphate layer and an energy consumption, which will not increase in total, and a pay-off time of the investment no longer than three years.

Project realisation

The methodology will be to evaluate and develop the technology of recovery in an industrially realistic pilot plant. The results from the pilot plant trials will be verified in production plants by using by-passing water flow from rinsing and phosphate pre-treatment baths. The composition of the concentrate and the effect on the coating quality will be analysed and ways to detect and eliminate disturbing elements will be developed.

To assure the coating quality at different degrees of recovery of chemicals

The pilot plant at Swerea IVF for dip surface treatment will be adapted and completed to resemble the selected production plants.

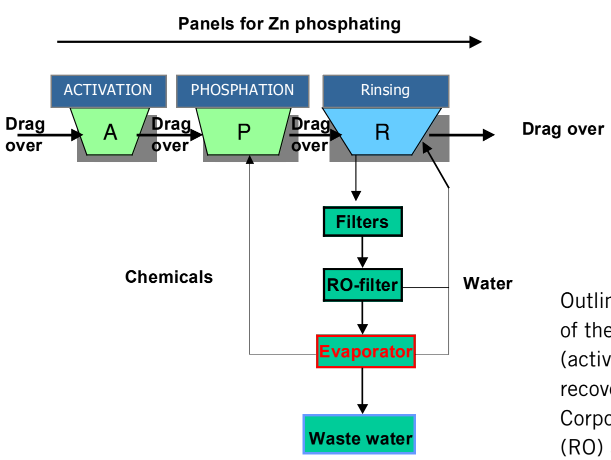
In the Volvo Car Corp plant reverse osmosis (RO) and evaporation were chosen as the most suitable techniques for recovery. The premier task was to establish the requirements on the evaporator. In the pilot plant all steps will be set up to facilitate proper surface treatment and evaluation. The three baths, which will influence the result of the recovery of chemicals (activation, phosphate pre-treatment and rinsing) will be the same as in the actual production plant.

Test specimens of steel, aluminium and zinc coated steel will be selected of the same quality and in the same proportion as the work pieces passing through the production plant. These specimens will be phosphatised as various portions of the concentrate, which is produced by the evaporator, are recovered. The coating quality is evaluated with respect to maximum degree of recovery allowed. Essential questions to investigate are: What pollutants are developed or enriched? What quantities of each pollutant respectively can be accepted without the quality being deteriorated? How can the quantities of the pollutants be registered on-line and removed? How should the supplementary composition of chemicals be determined?

To assure the coating quality at steady-state production in the pilot plant

The pilot plant is adapted to large scale phosphate pre-treatment in a rational (automated) way. Recovery of concentrates is performed from evaporator to phosphate pre-treatment bath in the amount that earlier tests have proven optimal. The same is valid for the permeate, which is retrieved to the rinsing bath after the phosphate pre-treatment.

Test specimens of steel, aluminium and zinc coated steel will be selected from each company respectively, proportionally and in a condition resembling the production circumstances. The specimens are phosphate pre-treated until a steady-state is reached concerning chemicals, pollutants, etc. This step also includes the design of the system of supporting chemicals and tuning of the remaining process parameters.



Outline diagram (explanatory sketch) of the three most critical process steps (activation, phosphation, rinsing) and the recovery system selected for Volvo Car Corporation, filtering, reverse osmosis (RO) and evaporator.

Production follow-up of critical moments

Based on the results obtained in earlier tests and the conditions of each company respectively it is decided 1) how the optimal recovery system concept should be designed, 2) how the critical parts of the system should be identified and 3) what production-relevant follow-up will be needed at each company.

Based on the results from the tests a plan is developed for each company for the upscaling to full production. The plan includes a complete mass balance of chemicals and water flows, and a calculation of how the total energy consumption and the costs are affected.

Project impact

The project should render possible that recovery of chemicals and water is performed as much as possible without lowering the quality. If the project is successful (and the results positive) each participating vehicle company will be able to implement the technique in several of their plants. A continuation project is planned to facilitate the implementation of the technique at suppliers.

Participating parties and Contact person

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Research performers are

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Optimisation of industrial production systems with simulation aid

Objective

On-line programming and verification necessarily disrupts ongoing production and reduces total production throughput due to downtime. Production lead-times can be reduced significantly by the utilisation of general methods for off-line programming, optimisation and verification of control logic that executes associated industrial processes.

Results and deliverables

Optimization strategy

Optimization strategy is expected to run in real production within project time.

Increase knowledge of production simulation

A functional mock-up where the optimization strategy can be tested and verified.

Project realization

The scientific goal of this project is to find methods to optimize complex and highly automated production lines such as a press line with help of simulation techniques Project outcomes.

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Production systems - assembly

4D Ergonomics

At present, there are a number of simulation and visualization programs available on the market to evaluate ergonomic aspects of manual assembly work. These programs are mainly used for visualization of assembly tasks. In a limited subset of these studies, established and/or corporation-specific ergonomics evaluation methods have been integrated into the software. However, the static evaluation methods that are available today generally yield assessments that are too coarse. Therefore, there is a need to introduce dynamic ergonomics methods, focusing on entire movement sequences instead of discrete static postures. Furthermore, ergonomics are seldom related to aspects of quality, despite the fact that numerous studies have shown high correlation between ergonomics in assembly and product quality outcome.

Objective

The objective of the 4D Ergonomics project is to develop methods and models pertaining to physical ergonomics in production and its relation to productivity, quality outcome and health.

Results and deliverables

The project has delivered following relevant output, both from industrial and academic perspectives:

- A models describing the relationship between quality outcome and physical ergonomics
- An ergonomics evaluation method considering the variations of physical workload over time for the wrists
- A demonstrator applying the relationship and workload mentioned above
- Recommendations of which available simulation methods best predict the actual movements of assembly workers
- Recommendations regarding which work sequences are suitable for validation in each simulation method respectively
- Case study comparison of a corporate internal assessment method with a national standard method
- Comparison between ergonomics simulation results and the real output in the plants
- Scientific papers published in international journals and presented at conferences

Project realization

Relationship between quality outcome and physical ergonomics

The model describing the relationship between quality outcome and physical ergonomics is based on a study carried out at Volvo Car Corporation in Torslanda. The study is based on a selection of assemblies of high, medium and low physical work loads. 24 443 cars are included in the study. These assemblies were followed and evaluated with respect to quality errors for an eight week period in production and another four months period on the after-sales market. The numbers of quality errors were registered and the costs for scrap and corrective quality actions were calculated as well. For each ergonomic risk level the purpose was to define an associated quality cost. The results show an increased risk for quality errors of the product for assembly items of high and moderate physical work load compared to assembly items of low work load. The risk is increased 6-7 times. The cost for corrective measures of the products in the plant are more than 12 times higher for assembly items of high and medium physical work load compared to items of low physical work load. A practical benefit from the results is that the model for total cost calculations can be applied in the decision of product concepts and assembly solutions for proactive cost-benefit analyses on detailed product level and with addition of health-cost calculations for work related sick-leave and rehabilitation because of musculoskeletal disorders.

The study will be submitted to an international scientific journal during 2008, and serve as base for a cost-calculation model in the demonstrator.

An ergonomics evaluation method considering the variations of physical workload over time for the wrists

An evaluation method based on a manikin's wrist movements is under development and will be possible to use before physical prototypes are available, with methods used for ergonomics simulations and electrogoniometer data analyses. The human simulation and visualisation program Jack and an electrogoniometer analysis software was used. A program in MatLab was written to resample data generated in human simulation and visualisation into a lower frequency and a rotated coordinate system to fit definitions in the electrogoniometer analysis software. The MatLab program also generated output files in a format recognised by the electrogoniometer analysis software. The exposure data obtained from an ergonomics simulation is set in relation to other occupation groups investigated by Hansson et al. (1996). The setup of the motion capture system, virtual environment, mockup, subject, digital human model, static ergonomics tools, and dynamic ergonomics tool (electrogoniometer analysis software) is shown in Figure 1. The described evaluation method will be submitted to an international journal during 2008.

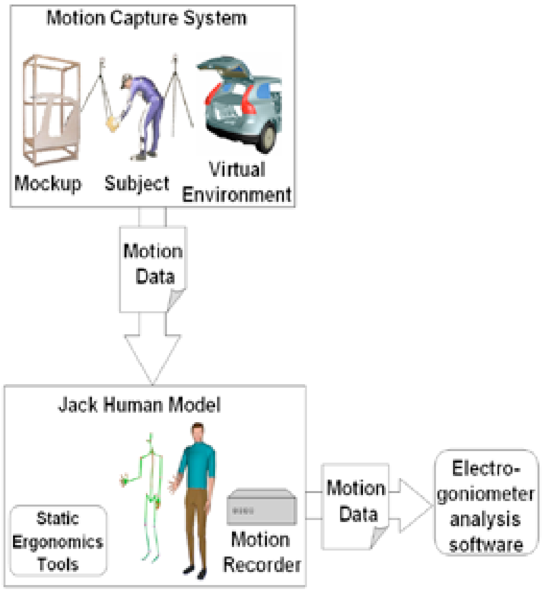

Figure 1. The setup of the motion capture system, virtual environment, mockup, subject, digital human model, static ergonomics tools, and dynamic ergonomics tool (electrogoniometer analysis software).

Reference

Hansson G-Å, Balogh I, Ohlsson K, Rylander L, Skerfving S. (1996). Goniometer measurements and computer analysis of wrist angels and movements applied to occupational repetitive work. In: Journal of Electromyogr Kinesiol, Vol. 6, pp. 23-35.

A demonstrator applying the relationships and workload mentioned above

A demonstrator is under development and will be a part of the project's outcome. The input algorithms to the demonstrator are sofar not completed. However, the setup for such a demonstrator is ready and the demonstrator will become a reality before the project is finished.

Figure 2 shows a proposal of what the demonstrator could look like.

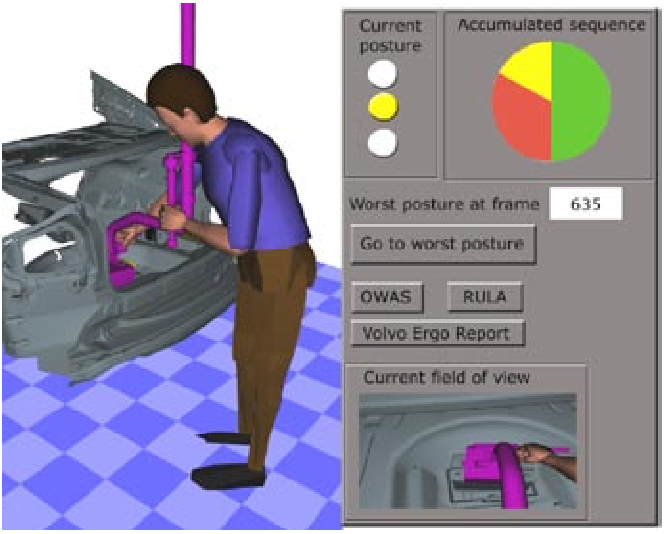

Figure 2. A proposal of what the demonstrator could look like.

Case study comparison of a corporate internal assessment method with a national standard method

In this study, a corporate-internal method with a highly specified input protocol (BME) was used to evaluate the ergonomic status of a production line. At the time, the evaluation was carried out by factory personnel with specific training in using the method. Months later, the same factory segment was re-evaluated by two professional ergonomists from an occupational health service, this time using the National Standard provision AFS 1998:1 as a basis. This provision was purposely formulated in a very general, non-specific manner in order to be relevant for a large variety of industries.

The study resulted in a submitted journal article that compares the two methods quantitatively and qualitatively, finding some similarities and also some interesting differences. It was found that the majority (59,5 %) of station ratings (on a three-zone colour scale) were identical, with some rating differences appearing in consecutive clusters, and that the national standard-based procedure tended to give more severe ratings. The ability of the methods to identify body segments at risk was also compared. The quantitative comparison was followed up with interviews, where the influence of professional tasks and objectives became evident, as well as the fact that evaluation criteria are interpreted differently by the two procedures. This is significant in the discussion of whether the two procedures are 'successful' in identifying and ranking ergonomic risks.

The main findings concern the difficulties of choosing the right evaluation method for a large, complex industrial system. Not only do different evaluation methods tell us different things at different levels of detail, but they also require very different competencies from the persons who perform the evaluation. Industrial corporations wishing to monitor ergonomics are advised by the researchers to ensure that ratings from evaluations are interpreted the same way by all involved personnel, and to ensure that the data output needs of each professional group is met.

Comparison between ergonomics simulation results and the real output in the plants

The objective of the study was to examine to what extent ergonomics simulations of manual assembly tasks correctly predict the real outcomes in the plants and if recommended measures originating from ergonomics simulations are taken into consideration. 155 ergonomics simulation cases were used in the study and all cases were performed by nine simulation engineers at Volvo Car Corporation in Gothenburg. The evaluations of the ergonomics conditions of the simulated tasks were done by six professional ergonomists working at Volvo Car Corporation in Gothenburg. The results show that digital human modelling tools (DHM-tools) are useful for the purpose of providing designs for standing and unconstrained working postures. Furthermore, the design of various auxiliary devices and their needed space for movements is a prevalent use of DHM-tools. However, the study also identifies areas that require additional development in order to further improve the digital human modelling tools' possibility to correctly predict a work task's real outcome, i.e. hand access, push pressure and pull forces, leaning and balance behaviour and field of vision. Moreover, a better feedback of product and process changes and a more careful order desription of simulation cases to the simulation engineers would lead to improved simulation results in current and future projects. Figure 3 shows examples of simulation tasks hard to simulate. The study resulted in a submitted journal article and in recommendations how the ergonomics simulation process can be improved to obtain more accurate ergonomics simulation results.

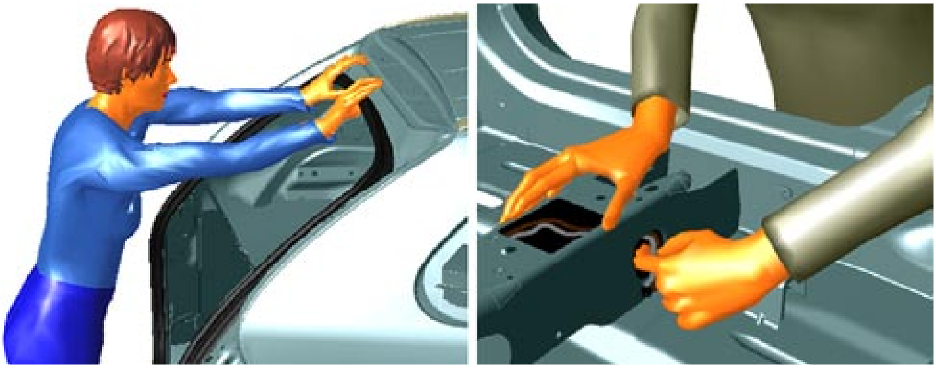

Figure 3. The incapability of evaluating pressure / pull forces are sometimes the reason behind deviations between simulation results and reality. Another reason for deviation is an underestimation, or an exaggeration, of needed space for the hand / arm.

Project outcomes

Published journal and conference papers:

Lämkull, D., Hanson, L. and Örtengren, R. (2008). Uniformity in manikin posturing: A comparison between posture prediction and manual joint manipulation. Accepted for publication in International Journal of Human Factors Modelling and Simulation.

Örtengren, R. (2008). Virtual Ergonomics Centre - A research arena for digital human simulation and ergonomics evaluation. Proceedings of the 40th annual Nordic Ergonomic Society Conference, Reykjavik, Iceland, August 11-13, CD-ROM.

Berlin, C., Örtengren, R., Lämkull, D. and Hanson, L. (2008). National Standard vs. Corporate-Internal Ergonomics Evaluation - an Industrial Case Study. Proceedings of the 40th annual Nordic Ergonomic Society Conference, Reykjavik, Iceland, August 11-13, CD-ROM.

Falck, A., Örtengren, R. and Högberg, D. (2008). The influence of assembly ergonomics on product quality in car manufacturing – a cost-benefit approach. Proceedings of the 40th annual Nordic Ergonomic Society Conference, Reykjavik, Iceland, August 11-13, CD-ROM.

Högberg, D., Bäckstrand, G., Lämkull, D., Hanson, L. and Örtengren, R. (2008). Industrial customisation of digital human modelling tools. International Journal of Services Operations and Informatics, Vol. 3, No. 1, pp.53–70.

Lämkull, D., Berlin, C. and Örtengren, R. (2008). DHM - Evaluation Tools. In: Handbook of Digital Human Modeling: Research for Applied Ergonomics and Human

Factors Engineering. Duffy, V.G. (Ed.). Taylor & Francis, CRC Press. Full book chapter, release date Nov. 18, 2008.

Hanson, L., Högberg, D. and Nåbo, A. (2008). DHM in Automotive Product Applications. In: Handbook of Digital Human Modeling: Research for Applied Ergonomics and Human Factors Engineering. Duffy, V.G. (Ed.). Taylor & Francis, CRC Press. Full book chapter, release date Nov. 18, 2008.

Lämkull, D., Örtengren, R. and Malmsköld, L. (2008). DHM in Automotive Manufacturing Applications. In: Handbook of Digital Human Modeling: Research for Applied Ergonomics and Human Factors Engineering. Duffy, V.G. (Ed.). Taylor & Francis, CRC Press. Full book chapter, release date Nov. 18, 2008.

Berlin, C. (2007). On the Development of a Time Sensitive Ergonomics Evaluation Method. Proceedings of the 39th annual Nordic Ergonomic Society Conference, Lysekil, Sweden, October 1-3, CD-ROM.

Lämkull, D., Troedsson, K. and Falck, A-C. (2007). Virtual ergonomics within Manufacturing Department at Volvo Car Corporation. Proceedings of the 39th annual Nordic Ergonomic Society Conference, Lysekil, Sweden, October 1-3, CD-ROM.

Bäckstrand, G., Lämkull, D., Högberg, D., De Vin, L.J. and Case, K. (2007). Reduce of ergonomics design flaws through virtual methods. Proceedings of the 39th annual Nordic Ergonomic Society Conference, Lysekil, Sweden, October 1-3, CD-ROM.

Högberg, D., Bäckstrand, G., Lämkull, D., De Vin, L.J., Case, K., Örtengren, R., Hanson, L. and Berlin C. (2007). Towards Dynamic Ergonomics Analysis of Work Sequences in Virtual Environments. Proceedings of the 17th International Conference on Flexible Automation and Intelligent Manufacturing (2007 FAIM), Philadelphia, USA, June 2007, pp 581-588, ISBN 978-1-4276-2092-7.

Wegner, D., Chiang, J., Kemmer, B., Lämkull, D., and Roll, R. (2007). Digital Human Modeling Requirements and Standardization. 2007 Digital Human Modeling for Design and Engineering Conference and Exhibition, June 12-14, Seattle, Washington, USA.

Falck, A-C. (2007). Virtual and Physical Methods for Efficient Ergonomics Risk Assessments - A Development Process for Application in Car Manufacturing. Department of Product and Production Development, Chalmers University of Technology, Gothenburg, Sweden. ISSN 1652-9243 ; 21. Licentiate thesis.

Lämkull, D. (2006). Computer Manikins in Evaluation of Manual Assembly Tasks. Department of Product and Production Development, Chalmers University

of Technology, Gothenburg, Sweden. ISSN 1652-9243 ; 14. Licentiate thesis. The project group has also acted as session leaders for several conferences:

- Nordic Ergonomics Society (NES) conference in Lysekil, Sweden, October 2007.
- Nordic Ergonomics Society conference in Rekjavik, Iceland, August 2008.
- Society of Automotive Engineers' Digital Human Modelling conference in Seattle, USA, June 2007.

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For more information about the 4D Ergonomics project, please consult the webpage of Virtual Ergonomics Centre, www.vec.

Flexible Lineside Materials Supply

Flexible Lineside Materials Supply (FPM) develops and evaluates materials supply solution combining a high efficiency with a great flexibility. A central part of this is to create efficient delivery systems where small unit loads can be delivered and presented in a way that supports efficient assembly. Within FPM, different concepts which support these principles have been tested and developed. *Tugger trains* constitute a means of transport which efficiently can be used for deliveries of small unit loads of this type. FPM develops knowledge regarding how such delivery systems should best be designed and controlled, for example to be able to include also heavy and unwieldy parts. *Minomi* is a concept where parts are handled and presented without packaging, which results in a space efficient display that supports variant flexibility and time efficient assembly. *Kitting* has similar effects, but is based on parts being delivered to assembly in pre-sorted kits.

Objective

The project Flexible Lineside Materials Supply (FPM) focuses on developing and evaluating materials supply solutions which can combine a high efficiency with a great flexibility. A materials supply system with these characteristics is seen as a central prerequisite for achieving a competitive assembly, capable of satisfying increasing customer demands for a wide range of products and tailor-made solutions.

The overall aim of the project is to contribute to a necessary development of robust materials supply strategies combining high cost efficiency with a high dynamic flexible within lineside materials supply. One of the aims of the research project is to develop a framework for evaluating materials supply strategies based on cost, efficiency and flexibility. FPM thereby contributes to a more long-term perspective in the decisions, helping both the logistics function and the production function. The project results in scientific knowledge extension as well as practical use for industry. The research includes knowledge of alternative materials supply methods, relations between them, design parameters, and performance measures. Focus is on the materials supply-related processes taking place within a production facility, including transportation, storage, parts picking, and delivery and presentation of parts to final assembly.

Results and deliverables

In line with the project aim of combing flexibility and efficiency, the focus has been on materials supply solutions which in an efficient manner can achieve small delivery quantities and enable a space efficient parts presentation at the receiving assembly station. A key to accomplishing this is to enable a transition from using forklift trucks for delivering parts to instead using tugger trains. Within Swedish industry, this transition has already started, but the knowledge is still limited as to how systems for tugger train deliveries are best to be designed and controlled, especially when it comes to heavy and unwieldy parts.

In order to create an overview and a starting point for the rest of the work, a study was performed early on in the project, focusing on determining which materials supply solutions that are currently used within Swedish vehicle assembly industry, as well as which areas that are in need of further development. The study was largely based on interviews performed within Saab, Volvo Car Corporation, Volvo Trucks, and Scania. The results were put together in the research paper *On the choice of approach for materials supply to mass customised line* assembly, which was presented at the "PLANs forsknings- och tillämpningskonferens" in Jönköping, September 2007. The paper indicates that within Swedish vehicle assembly industry, relatively limited knowledge exists regarding several of the concrete effects of using different materials supply concepts. Another finding was that forklift deliveries are very common, even though there is an ambition within the companies to change this.

An important part of FPM has been to study the alternative materials supply concept of *minomi*. Minomi can be used for example to enable tugger train deliveries of heavy and/or unwieldy parts. The principle behind the concept is to handle and present parts without packaging, which brings several benefits, such as space efficient presentation and elimination of package handling, but which also brings new demands for the materials supply system. A number of implementations of minomi solutions have taken place within Saab and FPM has played an important role in developing and introducing these solutions. Figure 1 is a picture of one of the introduced solutions, showing a minomi solution for presenting parts in a space efficient manner that facilitates picking for the assembler. Furthermore, a number of case studies of the minomi solutions have been made within FPM, which among other things has resulted in the research paper *Effects of using minomi in lineside materials supply*, which was presented at the international EurOMA (European Operations Management Association) conference in Groningen, Holland, in June 2008. The paper presents both positive and negative effects which can arise as a result of introducing minomi. Among the positive examples is the fact that a more space efficient parts presentation can be achieved, which in one case could be used to reduce the combined length of the component racks at the assembly station by 77 %. Another potential benefit was found to be that the more space efficient parts presentation could be used to place the parts in better picking positions, which in turn could reduce the handling time for the receiving assembler. To achieve efficiency also in the materials supply phase, it seems that minomi should be introduced primarily in deliveries from internal processes, as some form of repacking otherwise is likely to be required.

Yet another research paper is being prepared and will be presented at the international ”Swedish Production Symposium” in Stockholm, November 2008. This paper is based on a computer simulation of a number of material flows with the body shop of Saab. The aim is to investigate how ordering principles, delivery quantities, delivery frequencies, and buffer sizes should best be adapted in order to achieve efficient tugger train deliveries in a production environment with a large number of part variants as well as a fluctuating production rate. This simulation is performed in cooperation with University West in Trollhättan, which participates in addition to Saab and Chalmers.

In addition to this, FPM also supports a project within Saab where a number of introductions of kitting are taking place. The principle of materials supply by kitting is that parts are delivered to assembly in kits, each of which has been prepared for an assembly object. This enables a space efficient presentation of parts and can also support the assembly work and contribute to a high product quality. As support to the implementations within Saab, FPM contributes with knowledge from academia as well as with evaluations and recommendations regarding the steps that are taken. At a later stage, this is planned to result in another research paper, presenting conclusions regarding suitable areas of use, as well as appropriate systems design. Figure 2 and figure 3 are taken from a kitting implementation at Saab. Figure 2 shows the parts picking for the kits, whereas figure 3 shows how the parts are presented at the assembly.

Academic publications from FPM so far:

- Hanson, R. and Johansson, M.I. (2007), “On the choice of approach for materials supply to mass customised line assembly”, In: *PLANs forsknings- och tillämp ningskonferens 2007.* Jönköping, Sweden 5-6 September 2007.
- Hanson, R.: “Effects of using minomi in lineside materials supply”, In: the EurOMA conference, Groningen, Holland 16-18 June 2008.

Figure 1: Space efficient minomi presentation of parts at assembly

Figure 2: Parts picking for kits

Figure 3: Presentation of kit at assembly

Project realization

FPM is run as a cooperation between Saab and the Division of Logistics and Transportation at Chalmers. At the start of the project, Saab hired an industrial PhD student who was to focus his research on the areas included in FPM. This way, a natural and strong connection has been established between Saab and Chalmers, which has contributed to a mutually beneficial exchange between industry and academia. This exchange has been further enhanced through the involvement of University West in one of the studies performed within the project. Cooperation and knowledge exchange has also taken place with other companies in Sweden, such as Volvo Car Corporation, Volvo Trucks, Volvo Powertrain, Scania, Pininfarina, Parker Hannifin, BT Products, and Asko Cylinda.

Apart from the interview study performed at Saab, Volvo Car Corporation, Volvo Trucks, and Scania, most of the other results from FPM have been collected from case studies performed within the Saab production facility in Trollhättan. These case studies have been based partly on simulations and calculations and partly on physical implementations of concepts of interest, such as minomi and kititng. The studies of these physical implementations have been based on direct observations and measurements, as well as on video analyses, which have enabled more detailed time studies. For example, the work performed at the receiving assembly stations has in many cases been recorded and analysed in detail in order to establish the effects that the materials supply has on the assembly work. The studies that have been performed have focused mainly on the effects in terms of efficiency and flexibility to handle a large number of part variants as well as variations in production rate, as these characteristics are seen as central aspects of a competitive production system.

There has also been a collaboration between FPM and the MERA project Flexible Assembly, which is run in cooperation between Saab, Volvo Car Corporation, Chalmers, University West, and Innovatum in Trollhättan. The aim of this project is to develop production systems capable of efficiently producing cars with traditional drivetrains together with cars with alternative, environmentally friendly drivetrains. FPM has here contributed with knowledge regarding flexible materials supply systems, which constitute an integral part of a flexible production facility.

Project outcomes

FPM has contributed to the development and understanding of materials supply methods which combine a high flexibility with a high cost efficiency. In the tough, global competition of the car industry today, these capabilities are imperative, as demands are pressing for a broad product range with customised products, which must be produced at a low cost.

The results which have been gerenated within FPM have been of direct use for Saab's production facility in Trollhättan, where the intention is to continue the project during 2009 and 2010. Furthermore, the results of the project have been spread within academia through the research papers which have been written and the conferences where the results have been presented. Another paper will be finished and presented during the autumn of 2008. The intention is then that the industrial PhD student who was hired at the start of the project will continue his research during 2009 and 2010 before presenting and defending his dissertation.

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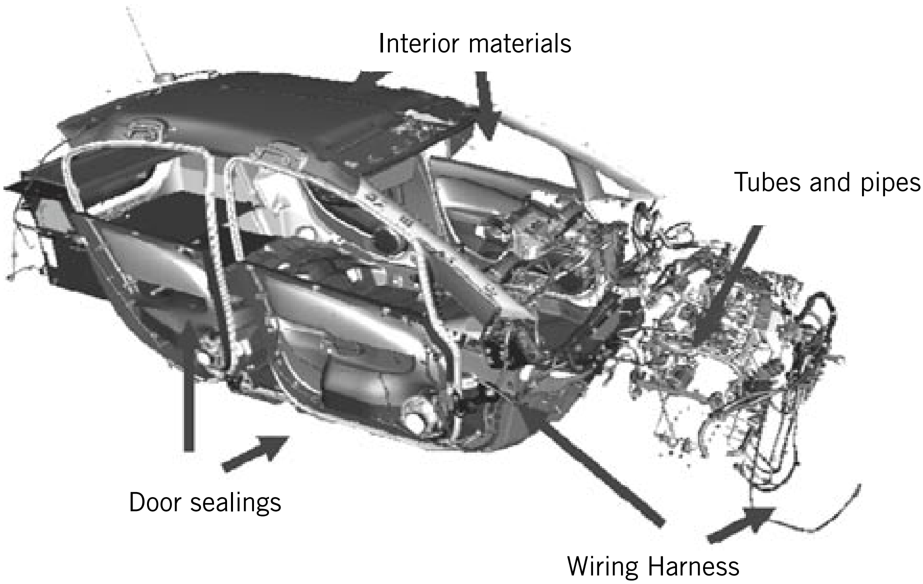
Simulation of Flexible Materials



Examples on different compliant parts in vehicle industries are air and fuel pipes, electrical cables/harnesses and robot hoses. The project goal has been to reduce the need for physical tests and hardware use and instead use virtual tools for validation. The project has resulted in methods, techniques and knowledge for real time simulation of flexible materials adapted to vehicle industries requirements. All included in a demonstrator with the ability to simulate and visualize the deformation of flexible materials with different material properties in real time. Forces and torque can be analyzed, hose and cable lengths can be optimized, clips be attached and movements analyzed.

Motivation

The project goal is more efficient and quality assured production preparation of flexible parts. Examples of flexible parts in automotive industry are air pipes, fuel pipes, electrical wires, and cables/tubes on robot function packages.

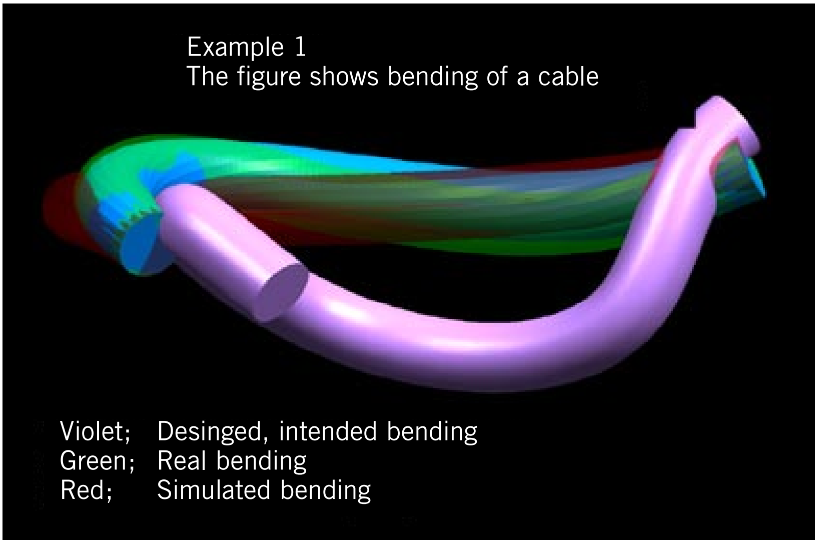
Result

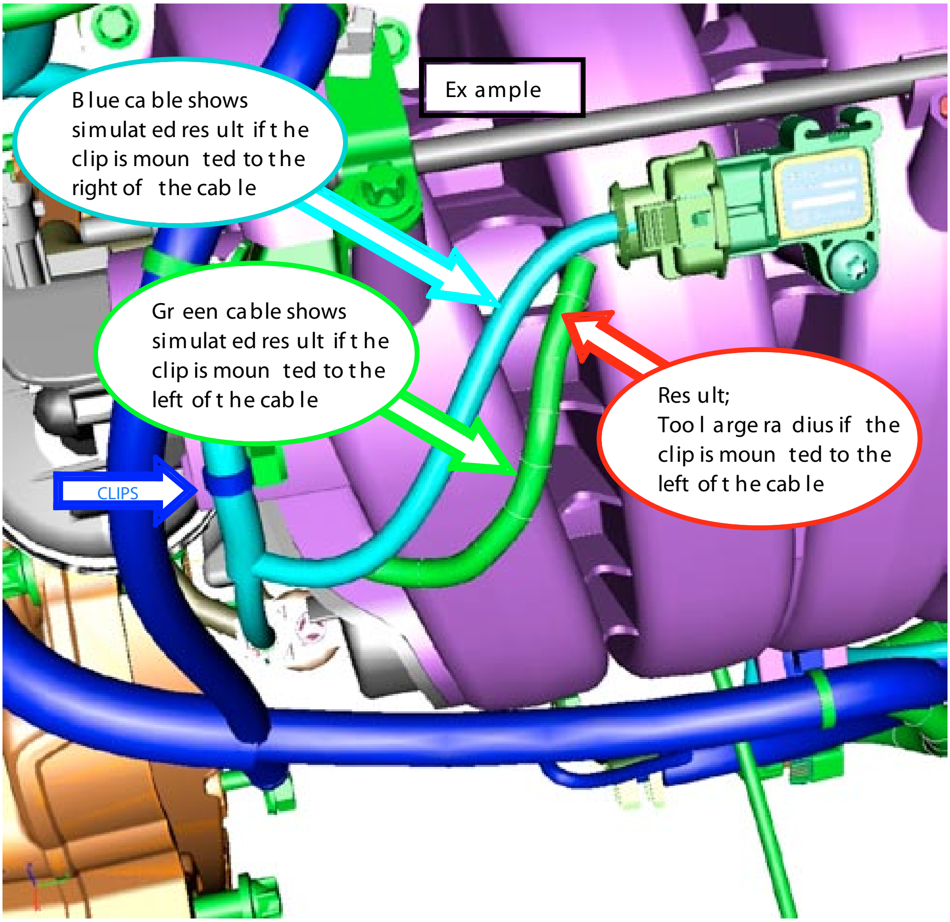
The systems used today for digital mockup lack simulation capability for supporting correct and reliable design and analysis for flexible parts. The objective of the project is to reduce the number of situations when preparation and validation require real prototypes and physical tests. The project also aims at fewer production stops, less material need, and products requiring fewer and cheaper reparations. The project and its results are expected to (i) generate validation results comparing measured data with simulated data (ii) be user friendly enough to be widely spread, and (iii) introduce flexible part simulation with real time capability.

Project realization

A mathematical model based on non-linear beam theory allowing for large bending, twisting and shearing has been developed and adapted to real time simulation of flexible cables. The model has been implemented in a software demonstrator in which the industrial partners can test the results in an early stage. Experiments comparing measured data with simulated data have been conducted. A database for material properties has been developed, and a model for computing the material parameters for wiring harnesses has been calibrated through measured data.

Results





- The project has generated a software demonstrator in which cables and wires of various material parameters can be simulated in real time. Forces and moments can be analyzed, cable length can be optimized, clips can be attached, and motions can be evaluated.
- Simulated results have proven to be accurate.
- The software is already used in real car projects.
- GM has decided to support the technology developed in this project as a global standard for simulation of flexible cables.
- Approximately 40 engineers at Saab/GM and Volvo Cars are trained in the software demonstrator developed in the project.

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Development of the concept ”Swedish Production System” (SwePS)

Swedish Production System (SwePS) is an effort to raise the awareness of Lean Production within the Swedish industry. The SwePS project is contributing to the development of sustainable production systems to increase the competitiveness of Swedish companies! A focus in the project is to utilize the strengths and possibilities caused by the Swedish cultural context.

SwePS has resulted in an increased knowledge through an extensive education program, exchange of knowledge within networks and case studies in companies. Here, the focus has been on their development areas related to Lean Production. The findings based on the participating companies' current and future challenges, with regards to the areas of improvement and development, assembly, materials handling and logistics, and cooperation in supply chains and production networks.

Objective

The purpose of the project is to strengthen the position of Swedish companies by educating staff members in and implementing the Lean Production philosophy based on the strengths, possibilities and the prerequisites of Swedish companies.

Results and deliverables

The following results have been accomplished:

- A broad base with personal in the companies (3000 people), have been given shorter education increasing the of what Lean Production means and can contribute to the implementation and maintenance of such a company culture.
- Leaders and lean coordinators (50 people) have taken extensive lean programs. They can facilitate the reformation of the production system and are be able to support the management in there leadership and supply the organisation with tools as the improvement work proceeds.
- Increased knowledge of how Swedish companies can use their strengths to increase their competitiveness and to develop sustainable production systems. There has been a specific focus on important considerations in Swedish companies where the Lean philosophy and overall principles are valid. However, it is difficult to directly implement Lean Production methods and tools, due to specific conditions, context, culture etc. An adjustment is needed to match the

company's technical, physical and business context as well as the cultural, human and organizational context.

- A network within the area of production and logistics has been developed with parties from the industry, institutes and academics. The network contributes to the exchange of knowledge and information and development within common interests.
- Education of 2 Ph.D. students and research projects for 5 post doc within university and institutes and 3 Ph.D. within the companies.
- Publications in scientific papers and popular science papers.
- Presentations of the results at scientific conferences and industry and practitioner oriented conferences.
- New and modernized education programs in Lean Production for undergraduate studies as well as continuing and professional studies.
- In the project, 14 case studies have been carried out or are in progress. The case studies have shown large potential in the different studied areas. In most of the case studies, the companies have continued and implemented the changes in their production systems.

Project realization

The project has been carried out during 2006 – 2008 in cooperation between parties from the industry, institutes and academics, in order to achieve a superior exchange of knowledge and information. The project has comprised of the following main parts:

1. Education within Lean Production for key personal (Lean game, Lean Production 7,5p at Chalmers University of Technology, etc).
2. Implementation of a number of fundamental Lean principles at a number of production sites (14 case studies focusing on different characteristics based on the existing critical needs for development in the companies).
3. Analysis and conceptual development with a theoretical as well as an empirical base (the 14 case studies), figure 1.

The project framework setup has given rise to possibilities to find synergies between the different parts of the project. The project is a cooperation between a number of different production units within the following companies; AB Volvo, Saab Automobile, Volvo Cars, companies from Scandinavian automotive suppliers group and participating researchers from Chalmers University of Technology and Swerea IVF AB.

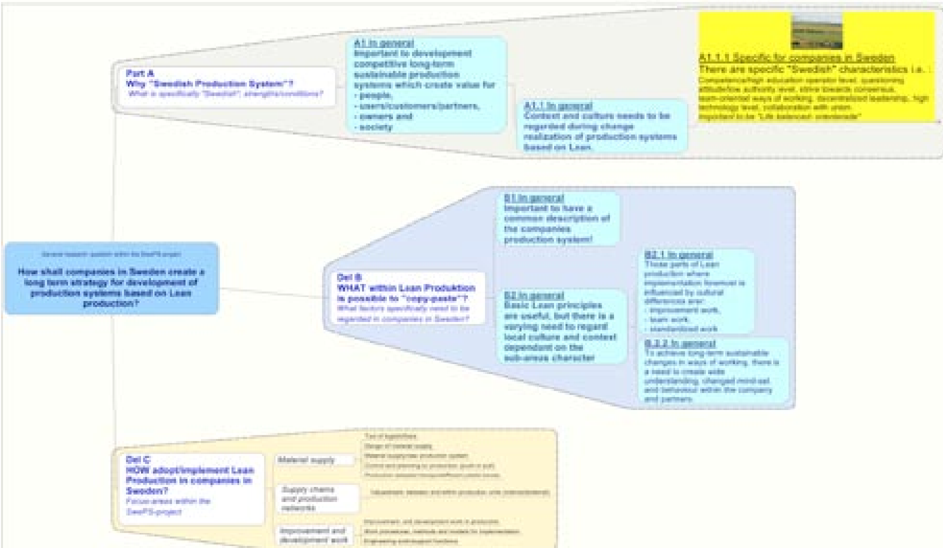

Figure 1. The SwePS- project help to increase the understanding about WHY, WHAT och HOW questions in the design of production systems, in Sweden, based on Lean Production.

Project outcomes

The project has resulted in effects in several dimensions, it has both participated to an improved competence in industry and to a deeper knowledge about what is important to consider when companies in Sweden want to design and develop long-term and sustainable production systems based on Lean Production. The project has contributed to an extensive growth of competence, a large number of people have participated in education, 40 persons have participated in extensive Lean courses, and more than 1400 persons have participated in minor courses in Lean Production. In total has 19 courses of "Lean Production", 7,5 university credit points, been accomplished by "Chalmers School of Continuing and Professional Studies", each course with approx. 25 pupils. The courses have been accomplished all over Sweden, from Sibbhult in south to Luleå in north. Besides Göteborg, the course has been given in seven other cities. The participants have been from many different business and size of companies.

In the *case studies involving materials handling*, the outcome has been very successful. All the participating companies have chosen to further develop the case study results by themselves. Promising results from an initial pilot study resulted in that the study was transformed to include the whole plant. The results from the initial case study have already been exceeded for the whole plant. Other case studies within materials handling included picking time reduction and how demands from the assembler is addressed to the materials feeding system and organization. The implications these demands have on the materials feeding system and organization, have influence on the design of new material handling methods. Another case study considered change of material racks at the assembly lines of the Volvo Penta plant in Vara. The results involved the possibility to produce one piece continuous flow on customer demand instead of batch production. Now the plan is to redesign the whole assembly line. Already has the materials feeding system been redesigned, meaning a supermarket with downsizing to smaller packages. One case study at Volvo Aero has proved that simple pull based principles for production activity control (ex. Kanban), can successfully be used in planning contexts characterized by long lead times and complex flows. This is planning contexts where pull principles, are usually not recommended. In this case study was two different pull principles compared, Kanban and Conwip. The resulting comparison showed obvious advantages for Comwip. The case study also implicated that, to be able to implement in practice, the pull based planning and control principles has to be adopted to and developed to planning contexts characterized by long lead times and complex flows.

The case studies related to supply chains and production networks has contributed to the understanding, how important it is to consider the whole value stream and how the whole flow is affected (both internal and external) at changes, within the company, between customer and supplier, between plants etc. For Swedish companies it is especially important to make use of proximity to partners and suppliers in the supply chain. By developing and applying the Value Stream Mapping methodology for supply chains, large potentials could be identified. The methodology can be used inside plants and along whole supply chains. Performance measures will assess the performance of the supply chain, i.e. to what degree the logistics system will fulfill demands from production (ex. the assembler). In the case study at Volvo Bus, their production philosophy has been made clear, based on principles from Lean Production. Education involving most parts of the organization has been realized. The project has resulted in new communication links between different plants, foremost between the body plant and the chassis frame plant in Uddevalla, leading to cost reduction. Changes in the production processes have considerably reduced the assembly time and materials cost and also increased the quality. From the case study at Saab Automobile, potentials for improvements have been found. Results from the study have been presented at an industry conference.

While studying on-going change processes in the industrial companies, the aim was to identify success factors, hindrances and prerequisites to achieve efficient implementation and sustainable development, i.e. studies of flow-oriented production, standardized work, and improvement work.

In the case studies related to improvement and development work (Volvo Powertrain, Volvo Construction Equipment och Ljunghäll) focus was both daily improvement work and major transformation projects, where the common challenge was to achieve changes related to attitude and willingness to adapt to standardized work. At Volvo Powertrain a pilot-line was re-built and several people educated. Philosophies where described and spread within the company. Positive differences of the operators working situation and improvement work were identified, in spite difficulties of following planned working procedures due to the stressed production situation. The case study has contributed in prioritized improvement suggestions for the company. At Volvo Construction Equipment a major Lean tranformation has started including company-wide education. The transformation has reached "half-time" according to plan, with very good results related to quality, space need, productivity and leadtime. Several minor-transformations of production cells are carried out during a period of 12 weeks, and is performed by a dedicated team during 12 weeks. The transformation is based on a structured plan based on Volvo Production System. The case study has contributed to identification of "lessons learned", success factors, and hindrances, which are documented and communicated with the company. At Volvo Penta in Gothenburg the increased part of Kanban together with other changes have resulted in positive effects, which not were obvious in the company. The pilot group, responsible for implementation of known improvements methods and tools also has shown changed attitude to contribute to development and willingness to change. At Ljunghäll AB personnel have been trained and support based on self-identified wastes is given for their further development improvement work in production. The approach has resulted in a great number of suggestions, however insights from the study is the great importance of support from management and support functions so that the personnel rapidly sees results of their engagement. The industrial studies stress the need to adopt working procedures, methods and tools to local conditions and that ways of working need to be continuously developed. Companies in Sweden need specifically to in early phases achieve a wide deployment in the whole organization, and that it is crucial that individuals have an understanding of WHY, i.e. a deep understanding of why a change is needed, benefits for the company, for the own work ets. Also personal engagement is important representing "local expertise". In other words the person closest a specific task should be in person involved in development work, or, in very close dialogue with engineers and managers. Regarding management, there is a frequent change of positions and roles in companies in Sweden which shows a need of strategies to cope with this phenomena and to strive to create continuous leadership related to changes.

At Volvo Aero work related to support functions in production have been studied with focus on production engineering areas as it has great impact on leadtime and product quality. The aim was to develop a tool for manufacturing engineers to better follow-up their work, plan, and visualize their work for partners and customers. Results show that the studied group increased the part of their planned work from 32 % to 50 %, which was positive and resulted in increased efficiency. Results has been documented in the Licentiate thesis "Some Findings on the Management of Production Engineering".

There are a number of effects on experience sharing (academic and industrial). For example, several collaborations between different industrial parties have started and been further developed. Knowledge dissemination has been done through publications and conferences, both scientific and practioner-oriented. This networking has been appreciated and fruitful as communication with colleagues from other companies and researchers has high lightened various issues of importance. The project results are planned to be presented in a number scientific works and industrial reports. Additional effects have been that SwePS-researchers has acted as coordinators in MERA-cluster and participated to exchange of experience between different initiatives within the MERA- programme, as well as contributed to initiatives to further research programmes within e.g. AFA (project ProVÅRD) and Vinnova (project KNOP).

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Efficient Assembly Preparation

The project has performed and documented a model for learning virtual tools that support efficient assembly preparation. However, efficient assembly preparation need systems that efficiently can exchange data between a companies existing data systems and the virtual tools that are to be used for assembly preparation. By using virtual tools the companies can reduce their needs for physical prototypes. This project has also studied the possibilities for this exchange between different tools and data systems and which questions that might be important to manage. Two important experiences from the project are:

Learning a new virtual tool and way of work takes time and must be given priority in the daily industrial schedule, and here it was shown that learning that have a goal or problem to solve is very efficient.

Development of a new way of work takes time and system integration needs a lot of engagement, it is important to know what you want to achieve when designing a new way of work.

Therefore, a companies organization and way of work demands a huge amount of time and effort when it comes to integration between existing data systems and a new virtual tool.

Objective

The overall aim is to develop a Swedish model for efficient assembly preparation work by using virtual tools in the early phases during the product realization process. The model is based on production of trucks and its specific demands. This will be reach by increase the knowledge within the area of virtual manufacturing and how it can support efficient assembly preparation.

The objective is to develop a Swedish model for virtual manufacturing supporting efficient assembly preparation for new trucks and variants of trucks. The focus is on the assembly preparation engineer role and responsibilities.

Project realization

Possibilities to improve the assembly preparation are studied through collaboration with assembly preparation engineers learning new virtual IT-tools. By using an action approach the researcher has studied several product related sub-projects and learning projects. Based on this knowledge and information a general model will be developed that supports analysis made by the assembly preparation engineer in a virtual environment. This model are left to the last part of this research project. During the project Linköping university has collaborate with Scania in Oskarshamn in several sub-projects. Furthermore, some interviews have been performed at other companies participating in the MERA-programme, such as Volvo and Saab.

Subproject 1: Assembly simulation

Summary of the results:

- The simulation precision is depending on the CAD models geometry information that supports the interfering with the product environment in the test assembly.
- Collisions are easy to identify with high accuracy when it is stiff components. Possibility to assemble can be decided based on high process know-how, which is not that easy when it comes to collisions during the assembly path.
- The virtual tools of today manages components with several moving joints.
- A model for learning virtual tools have been documented, see Figure 1.

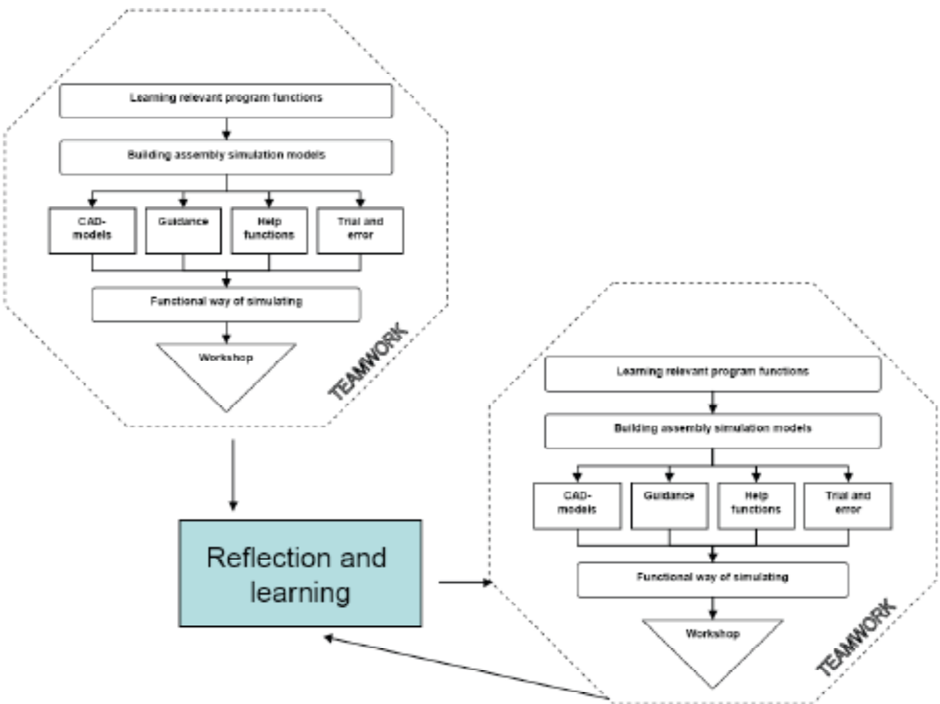

Figure 1: A model for learning virtual tools (Johansen et al, 2007)

Subproject 2: Assembly preparation of a production structure

The aim of the subproject:

- Identify how existing process information may be arranged based on models.
- Evaluation of management for variants in a model based way of working.

Summary of the results:

- Virtual models for 9 parts of a cabin variant are developed, and it is shown to be efficient to reuse processes and just change parts when converting existing process information from MPS systems to a PPR Hub (Product – Process – Resource – database).
- Management of variant in a PPR Hub is evaluated, it shows that knowledge about product and process is important when it comes to how to adapt the way of working so it is efficient in the virtual environment.

Subproject 3: Validation of working methods for virtual tools in combination with existing data structures

The aim of the subproject:

- How to work with virtual tools for product validation and process definition.
- Identify possibilities and limitations with implementation of a virtaul tool in combination with existing data structures.

Summary of the results:

- It is very important to define the aim of an intergration of different data systems and their structures.
- Connecting a product and a process in a virtual tool facilitates the preparation work for a simulation and supports the management of the huge amount of data.
- It is time consuming and demanding to develop a new way of work and integration of existing systems with new virtual tools that supports assembly preparation.

Project outcomes

This project has collaborate with Scania in their work to evaluate and implement new virtual tools that should work together with the existing data structures and support their product developmetn process. During the project and with some support form the project results Scania has continues their internal virtual tool training for assembly preparation in Oskarshamn and today there is one coordinator for virtual tools in Scania, Södertälje.

Scania in Oskarshamn has performed a competence exchange regarding simulation at Saab in Trollhättan (Researcher: Lennart Malmsköld), where both partners have projects in the MERA-programme. Other effects of this MERA-project is that Linköping university has got new relations and contacts at Volvo, Saab and Scania, and through these new contacts been invited as a participant in important competence kluster, such as the MDM-VM-kluster.

At the Linköping university it is identified that our new extended knowledge about virtual assembly preparation increasing our possibilities to train our new students in different ways, both in project works and at laboration. One lecture has discussed with participants in the different subprojects for developing new course material within the areas of assembly technology and simulation technology. There is an increasing industrial need of our students that have studied courses that use virtual tools, and this project facilitates the development of our know-how in the area of virtual tools. As an example 4 of our students that participated in subproject 1 are today employeed by Swedish industry in the area of virtual manufacturing: Scania in Södertälje has hired 2, Dassault Systèmes has hired 1 and Saab Aerospace in Linköping has hired 1, and all has an important position for their companies further development within the area of virtual manufacturing.

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Automated Body Shop Material Supply

What advantages can be achieved by using a system of sequenced container-free tugger train deliveries rather than fork truck deliveries? Could the need of manual packing and unpacking be eliminated and could this be achieved without lowering the total availability of the production system? These questions have been examined through testing of alternative solutions to an existing production system. The container-free alternative turned out to be an enabler for high flexibility as well as automation with high availability.

Objective

The project objective has been to increase flexibility and productivity within the field of body shop material supply. A basic assumption has been that long-term, cost effective flexibility is achieved by grouping dedicated equipment apart from a flexible main flow. Through this, the hard combination high flexibility / low complexity is achieved, simultaneous with an accentuated need of efficient material supply.

Results and deliverables

Within the project, a concept has been developed replacing fork trucks by tugger trains and eliminating manual handling of car body parts (see figure 1). The concept also means a reduced technical complexity and a lower level of investment compared to the state-of-the-art solutions. The essential functions of the concept has been build and verified in a test equipment (see figure 2).

A study of the effect on an existing production system showed a reduction of running expenses by 40 %. The reduction consists of two parts: 1) automation of the manual part handling and 2) a more efficient transport through the use of tugger trains as opposed to fork trucks.

Further, the number of work-in-progress was dramatically reduced. Between the sending and the receiving work cell, work-in-progress was reduced by 70 %.

The system, being sequenced rather than parallel, enables a vast number of variant. Product changes will not require structural changes. Small changes will only mean programming changes while large changes could mean that the cassettes will have to be exchanged.

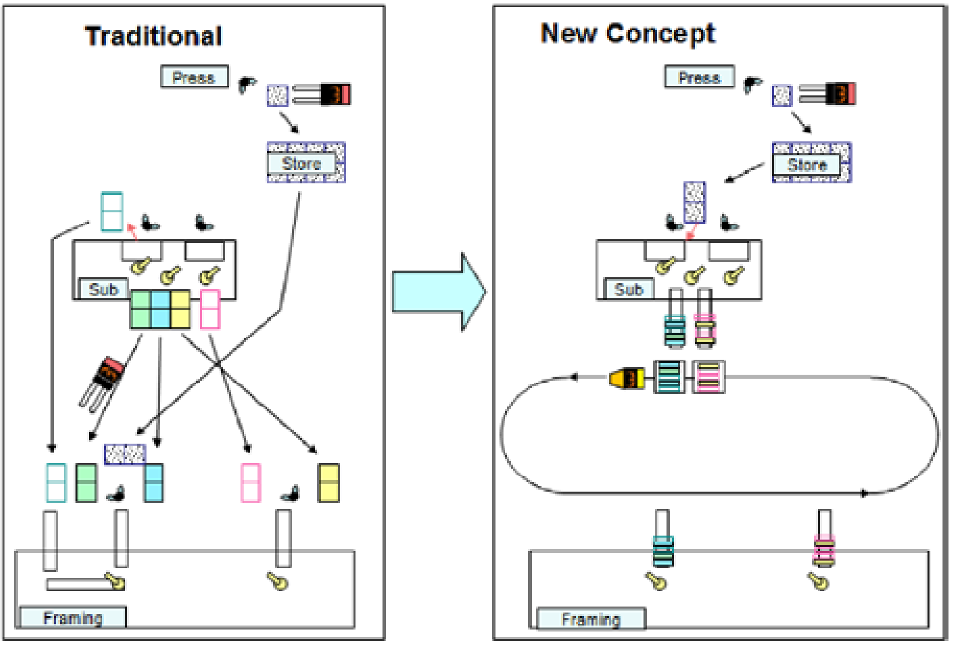

Figure 1. Production system with containers and fork truck compared to the new concept with tugger train delivery of cassettes from which the sequenced parts are picked by robot.

Figure 2. The essential functions of the concept, verified in a test equipment. This includes tugger cart, gravity powered cassettes, car body parts and robot system guided by vision.

Project realization

The project team with participants from Saab Automobile, LKN Industriautomation and Sensor Control has brought together competences of industrial engineering, robot technology, machine design and vision technology. Two thesis works has been completed within the project.

A technical concept has been developed and applied based on an existing part of the Saab Body Shop. Concept selection and try-out was made in a virtual environment in a first step, followed by physical tests were the selected concept was tested and verified in a test equipment.

The selected concept was based on a system known as "cassette minomi" when used at Toyota, a system mainly used for manual applications. This system means that containers are not used, instead parts are transported on cassettes flowing from the sender to the receiver and back again. The functionality was developed to fit in to an automated system and the concept was demonstrated in an installation that was incorporated in a robot cell placed at Innovatum Teknik AB in Trollhättan.

Project outcomes

Application of Lean Production is an area were the Swedish Automotive Industri have reached far, but the development in Japan and USA the last decade has created a gap, especially in the field of material supply methods. A-kamh has made a contribution to the closing of this gap by the development and testing of a solution based on these new methods. The project has created a significant increase of knowledge in the participating companies, and has also brought some of this knowledge on to other companies through demonstrations of the concept. A further outcome is the establishment of a common research project within the MERA-program involving Chalmers and Saab. This project, Flexible Lineside Material Supply, takes on a broader perspective and strives towards an extensive exchange with other industrial companies.

Distribution of results:

- Project presentation at the MERA Body&Cab cluster meeting, October 12, 2006.
- Presentation of the concept to members from the Örebro University, Mälardalen Högskola, Robotdalen and ABB. (October - December 2006)
- Project presentation at the MERA conference February 6, 2007.
- Demonstrations of the test installation have been carried out at 14 occasions with totally more than 50 participants from companies and universities. The participants were from Volvo Car, Volvo Truck, Helge Nyberg AB, Chalmers, University West, GM Europe, GM North America and Saab Automobile (January - March 2007).

Participating parties and Contact person

The participating parties has been Saab Automobile, LKN Industriautomation, Sensor Control AB and University West.

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Implementation of hybrid vehicles in production process

The car development and thereby the vehicle producers stand before the biggest previous change on the products ever. The world market's demand on crude oil with a rising price and the global heating caused of increased emissions of CO2 has direct impact on the development of the future's vehicles.

For the vehicle owners, the fuel cost and awareness about the contribution to CO2 the emissions wile use of fossil fuels done that newly automotive buyers neither chooses a green cars. Certain countries' governments allocate green automotive consumer advantages in the form of wealth discounts during the vehicle ownership.

A directly consequence of the market's increased demand on environment vehicles is that the world's vehicles' producers have accelerated the development of cars with alternative drive trains.

The development can shortly be described in replacing fossil fuel (diesel and petrol) and to do the vehicles ' drive trains more energy effective.

A technical solution in order to render more effective the vehicles' drive trains and thereby to decrease fuel consumption and environmental impact is electrical hybridization.

Production's plants are for vehicle producers long term investments and has long writing off's time. In order to hold production costs down and to retain the competitiveness is avoid of bigger investments and it is therefore important to guide the product development in through feedback of process requirements to product developers.

Electrical hybrid vehicles are for the production process an entire new product. The hybrid systems are of type" add on" systems to that existing combustion engine the drive train and additional entirely new components, systems and functions what will be built together and function's to be tested.

Existing production process can to be used but requires adaptation with new assembly stations for the new assemble the additional modules. For the production personal this will mean special education in function and security for the vehicle additional high voltage system.

This project acts about investigating and to take forward which requirements that are set on the product formulation, prepare and to adapt the production process for electrical hybrid vehicle and to map the need of education on operators in the production's process.

Objective

The central aim with this project is to develop a common production process and production system for future hybrid vehicles and conventional vehicles.

Since this project is a subproject to the PFF project" Hybriden" what also is running by Saab automobile Ab, it is also an aim to plan and to build the central project 's hardware in terms of demonstrators (mockuper) and an operational hybrid vehicle. That vehicle will later be used to testing and validation of a hybrid vehicle characteristics.

The project contributes to that build up a development center for R & D of hybrid vehicle in Trollhättan what is a condition for a long term development of unique knowledge and competence within hybrid technology and production of hybrid vehicles in Sweden.

Existed production process is adopted for the production of conventional cars with internal combustion engines in order to meet the future's needs of flexibility in concerning on alternative drive trains so is required it changes in the process as equipment, tools and knowledge in order to can to produce the tomorrow's cars on a competition considerable ways. Within the framework of the project is also the information to investigate the education need of production responsible and production personnel.

Results and deliverables

In and during the development process design loops, virtual evaluations and hardware build works have assessments, values and simulations done watches from a production point of view.

This in order to understand, address requirements and to set and define the manufacturing conditions the development in production and the production's management. From the facts optimize a production's process for both common vehicles and hybrid vehicles.

Process requirements against product

The requirements against the design department are in order to develop vehicles with hybrid system which will make them possible to produce them on an effective way.

Production communication off against development in production:

- assembly sequence
- max available assembly time
- equipment
- assembly ergonomics

- material handling of components (logistic requirements)
- programming and testing of vehicles in the production process
- personal security of handling high voltage components

The specific process the requirements against product have during the project's phases: structure, virtual evaluation and hardware build been validates both virtual and physical.

Process requirements

The purpose of requirements against production process is in order to inform and to prepare people that work with the future production processes. Before a decided production's start of hybrid vehicles must the production process be prepared and to be adapted, people will be trained and to be accustomed in good time then it hybrid vehicles architecture (components and systems) divides itself considerable from a conventional car and is more complex to learn to build.

Requirements against production's process:

- operational assembly's process‘s layout
- formulation assembly stations (assembly height, equipment ect)
- education of installers and production's management.

Virtual evaluation

Three loops with virtual evaluation of the package work mocks-up have been implemented. The first and other evaluation was done on the basis to the first generation's demonstrator.

The third virtual the evaluation was done on the basis to the second generation's demonstrator. This demonstrator shows a serial installation of "the strong hybrid systems" on next generation's platform.

Ergonomic simulation

In the frames of the MERA project 4D-Ergonomics has virtual working ergonomic simulations been done. Handling of high voltage battery to the vehicle and the attachment of the high voltage cable under heath to the vehicle are simulated. The aim is to optimize the assembly stations so that ergonomic the load on the assembly's operator becomes to low as possible.

Hardware construction work

In order to verifying and possible to validation of manufacturability has two generations hardware been built, demonstrators (mockupper).

The aim for these demonstrators was to reflect a series installation of the hybrid system on next generation platform.

Gen 1 demonstrator was built on the basis of other design/package loop and gen 2 demonstrator on the basis of 3é design/package loop.

Physically seen are the demonstrators build up on next generation platform and the details are produced in plastic on bases from the digital mocks-up.

The demonstrators has been built together during production correct conditions with respect to assembly sequence, equipment and tools. During the build monitoring the manufacturability in properties that: accessibility, assembly's ergonomic, tool needs, assembly time.

Analysis 's education needs

Within the framework of the project, the information is to investigate the education need of production responsible and production personnel.

The hybrid vehicle contains systems and components that are new for the vehicle industry, for instance the high voltage system. Important is also to get knowledge in how to handle a hybrid vehicle for instance after a collision and must be brought in.

Knowledge about these systems, repairs and regulations are a necessary in order to development and production of hybrid vehicles. Not be formulated product and process after these requirements is risk that people be injured. The outermost responsibility is carried always of the development/the producing company.

The result of the analysis is that all persons who work with development and production of hybrid vehicles must be trained in:

- Hybrid vehicles systems and functions.
- Electricity security
- Hart lung rescue
- Personal security and protection equipment.

All persons in PFF the project" Hybriden" and MORE the project" Implementation of hybrid vehicles in production process" has undergone these educations.

Programming and testing

In the production's process later part, it that be called" final", will the hybrid vehicles electrical systems excitement be set, programmed and diagnosed i e function tested. Next ascended in the production's process is start up of engine and run on rolls for control that engine and transmission functions that it is intended.

For a hybrid vehicle that has a drift system (electrical) analog with the conventional combustion engine so is added that electrical systems to excitement to set, program and diagnostic what adds assembly's time compare with a conventional car. Equal applies for start up and run on reels, it electrical transmission will sample queue avalanches and be checked.

Since new vehicles are provided with everything more functions and becomes more electronic complicated so is this part of the production's chain critical map time /bil (takt time).

Project realization

The end's situation for the central project was to integrate GM´s 2-mode hybrid systems on next generation platform. The intention was to implement a preliminary study where the combination hybrid with a diesel engine was studied. 2-mode hybrid system's basis components are developed for SUV´s and bigger pickup´s and already from the start was the one challenge concerning that few place (pack) all details.

For the project's implementation has Saab automobile product development process are used that mean one loop there **design - validation - feedback** is included. After some loops will the manufacturability be checked virtual or through hardware.

In the project has two loops been implemented and after that the first demonstrator was build. Then one moor loop and the final demonstrator that shows one series equal installation on next generation platform was build.

The hybrid car was developed and built as a mule i.e. that a combination of new and old architecture and is therefore out of interest from a production perspective.

Project outcomes

The implementation of this project and the investment in hybrid development centre has given an increased knowledge and competence within the area: The future's vehicles' fuel and drive trains.

This project has directly generated a new project in the "Gröna Bil 2 programme: Flexible assembly of environment cars. In the new project, the area has to be extended from production of hybrid vehicles to future bio fuels and hydrogen vehicles. Partners in this project are Volvo Cars, Chalmers, the college vest Innovatum technology park and Saab automobile.

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MERA conference 2008

Information systems in manufacturing

Effective information integration for Virtual Manufacturing (EVM)

The EVM project has worked with the development of data models and demonstrators for effective information integration for Virtual Manufacturing. Focus has been on the information backbone and its integration to point solution.

Objective

The EVM project focus on how information in existing, in-house developed or of the shelf, information systems should be integrated and made more accessible for Virtual Manufacturing, inkluding Virtual Manufacturing Engineering" (VM).

Information integration means that redundant data which can cause confusion and quality problems will be eliminated. It also gives the possibility to shorten the lead time in development projects and makes it easier to reuse data and information. However, there is a number of pitfalls that needs to be concurred before one fully can benefit of a manufacturing information backbone.

Results and deliverables

The project has developed a suitable information architecture and data model for handling information that need to be communicated between the different systems and which impact the information backbone will have on the production engineers working methods. The EVM project has focused on four different point solutions for VM. The project has also developed new automated ways to analyze manufacturing flows with information directly from the information backbone.

Project realization

The project have made requirement analyzes of data and information needed on four different point solution. Developed data models for how information should be stored in the information backbone and the development of automated information population from legacy systems. Finally, the project, has developed a demonstrator that demonstrates how information directly from the information backbone could be used for analyzing the manufacturing system in the point solution.

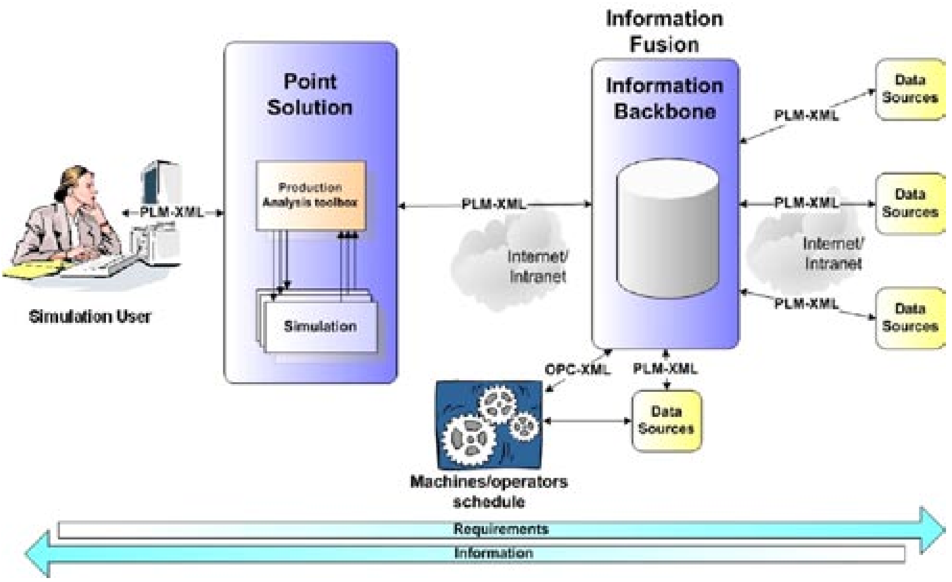

Figure 1 The usage of the information backbone for VM.

Project outcomes

In the EVM project knowledge on how to concur some of the problems with information integration for virtual manufacturing has been acquired. The project has also showed how changes in working methods could be with the use of effective information integration in a information backbone.

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Conceptual Plant Development, FACTS

Today, Swedish automotive industry has very limited support from working procedures, methods, and tools for analysis of complete plants in early program stages. This leads to difficulties in predicting the consequences from the early decisions that are basic for robust, flexible and cost effective production. The purpose of the project ”Conceptual Plant Development” is to provide for faster, more frequent, and better analyses of complete plants in early program stages. To achieve this, the complexity is reduced using abstraction methods, manual work with input and management of data is automated, and optimization is simplified thanks to simulation based optimization. The acronym FACTS reflects the projects aim to give production developers facts for well-founded concept decisions, with the support from simulation. Two prototype software tools have been realised by the project. The first – Generic Data Manager (GDM) – simplifies the gathering and configuration of production data from various data storages and thus automates the input to simulation analysis. The second – FACTS Analyser – makes it possible to easily model production, perform simulation experiments, and to optimize the system. Working procedures and tools have been tested at the participating companies, and possibilities for broader usage in Swedish industry was analysed. The industrial partners were Volvo Cars (project management) and a number of companies within the AB Volvo group: Volvo Technology, Volvo Powertrain, Volvo Trucks, and Volvo IT. Research partners were University of Skövde, Chalmers University of Technology, and Swerea IVF.

Objective

The project focuses on the work process of developing new production systems or introducing major changes. The aim was to support the early stages – the concept definition phase – and to ”frontload” the use of virtual (i.e. computer aided) methods to analyse complete factories. The motive for this focus is that it is in these early stages of development that costs are decided and locked, i.e. the decisions have high financial impact. Today, simulation is more often used in later phases when costs are locked and thereby opportunities affect solutions are very limited. However, an increased use of simulation requires support in developing abstract models, data handling and optimization. Analytical methods can be used to predict the capabilities of the factory. However, complete factories tend to be very complex to analyse, requiring experts, lots of time and advanced methods (queuing theory or stochastic process theory).

The project is focusing on analyses using production flow simulation, thereby providing for facts-based decisions. The goal is 50 % more analyses in conceptual stages, 20 % faster simulation projects, and higher precision in the analyses. The achieve this, complexity of models and data is reduced using abstraction methods, the manual work with data input and management is automated, and optimization is simplified using simulation based optimization.

Figure 1. In FACTS, methods and tools are developed that simplify analyses of factory concepts, using production flow simulation, making it possible to evaluate alternative concepts and to make well-founded decisions.

Results and deliverables

During the progress of the work provided the project has answers a set of research questions, and published these in a number of scientific papers:

- Which analytic methods for abstraction of factory systems can support quick evaluation of factory systems in early phases? How can abstraction be used to visualize future change scenarios?
- How can generation and handling of input data be made more efficient, to be able to automatically transform production and design data to fit the specific needs of the analysis tools.
- How can simulation based optimization be efficiently used to optimize development of factories in early phases and concurrently reduce time needed for manual simulation and experimentation?
- How should abstraction, input data management and optimization be combined to form a powerful tool?

The answers to these research questions have been the base for the development of and implementation of the technical results. The most apparent industrial objective was to combine analysis methods to form industrially feasible package of tools and methods. The technical results from the project was realised as two powerful software tools.

The traditional way of performing simulation projects requires a lot of effort and time in building models with many details, and gathering / managing all the data required by the model. This restricts the usage and users of simulation, although it has potential of being rewarding.

The tools realised in FACTS support such analyses in three stages, se Figure 2. First, by input data management is supported. Secondly, by abstraction of data and models, data management and model building is simplified. Thirdly, experimentation and optimization is automated providing faster analyses and better.

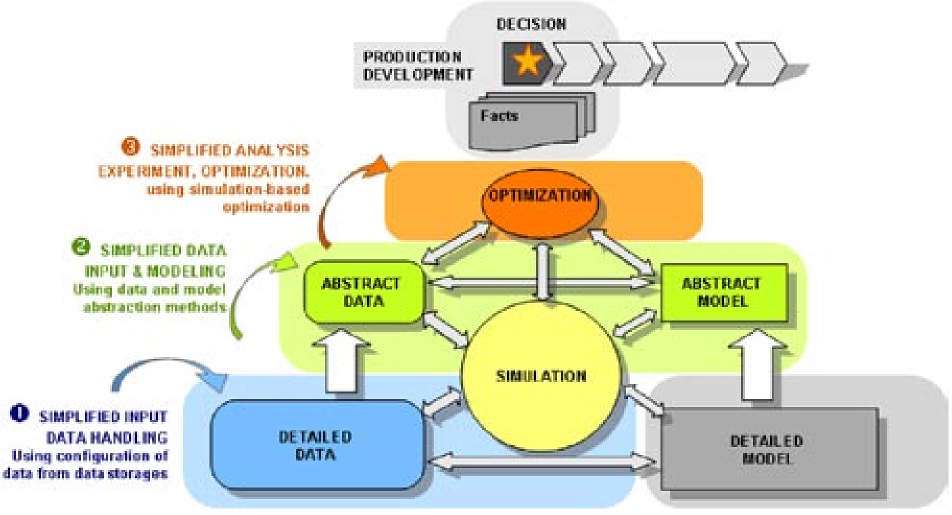

Figure 2. Prior to decision in early program stages, production analyses are needed, but the methods used today are too complex to be feasible (grey). FACTS support analyses in three stages. First, input data management is automated (blue). Secondly, by abstraction of data and models, data management and model building is simplified (green). Thirdly, experimentation and optimization is automated providing faster analyses and better (red).

Input Data Management

GDM-Tool consists of several elements, all of which together make it possible to transfer information from several production related databases to simulation models, e.g. process time, disturbance patterns, product sequence, see Figure 3. The data to be extracted is analysed and configured manually by means of a translator, e.g. how a stations mean time for disturbance are to be calculated from list in a production log. Once the data has been configured, the translation has been programmed and subsequent translations are made automatically. Based on this data, further information can be calculated using statistic methods. To make data management and interfaces to simulation software, the production information is stored in a standard format called CMSD, Core Manufacturing Simulation Data, that has been defeloped at NIST (National Institute of Science and Technology, USA)

In the project, software modules were developed that translates from CMSD-data to the simulation software packages Plant Simulation och Enterprise Dynamics.

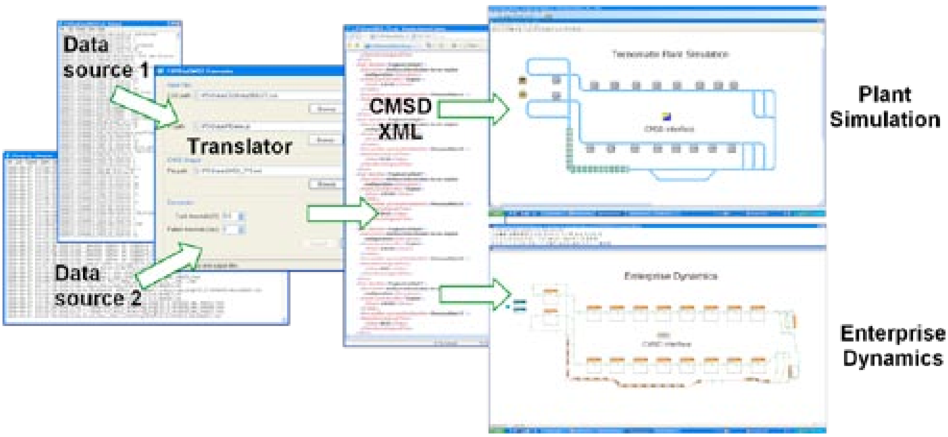

Figure 3. Data flow from two separate data storages, via configuration and CMSD file, to the translation and input to two simulation packages.

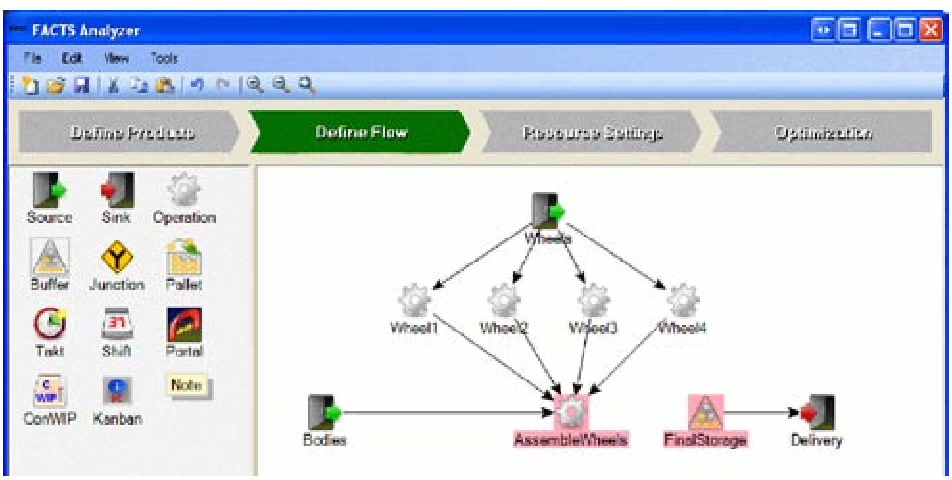

Figure 4. In FACTS Analyser an abstract model of the production is quickly modelled, using generic objects. The model is then easily simulated and optimized

FACTS Analyser

Using the second FACTS software, the engineer can build a simple (i.e. high level description) model of the production flow with stations and buffers. Information on the production and resources, process times, disturbance times, repair times, etc. is entered (see Figure 4). A pre-defined analysis work flow is followed: Define products → Define production → Resource settings → Optimization.

In the traditional simulation packages available today, the simulation engineer must then manually perform each simulation experiment on the model, analyse the results, change the model or parameters, simulate once again, etc. This is very time consuming, and this is where FACTS Analyser provides most support. The engineer gives basic data on the analysis needed, e.g. number of experiments, which parameters that are variable in the model (e.g. buffer sizes), and the goal function (e.g. minimize work in progress or maximize throughput).

The whole experimentation procedure is handled automatically by the optimization system. A plan of experiments is developed, and each separate experiment on the abstract model is distributed to a simulation engine. As soon as the simulation experiment is finished the results are sent back to the optimization system which sends a new experiment. Since more than 20 simulation nodes work in parallel, and since the model is very simple, thousands of experiments can be carried out automatically. The results of all simulations are collated and presented to the user who can chose optimal solution from e.g. a Pareto diagram.

Project realization

The project was been carried out Jan 2006 – March 2008 (see Figure 5) and have had a total budget of about 18 M SEK, funded by the participating companies and the MERA programme (Vinnova, Nutek, and the Västra Götaland region). The work showed unusually high degree collaboration among companies, academia, and institute. Volvo Cars has led the whole project but the separate work packages was led and managed by the appointed work package leaders.

The project was organized in five strongly related areas with separate focus: 1) Abstraction of detailed models, 2) Input data handling, 3) Optimization of solutions.

The first three areas are integrated to form and to fit established work procedures. This integration was focused in the integration package. The fifth work package holds the project and results information dissemination tasks.

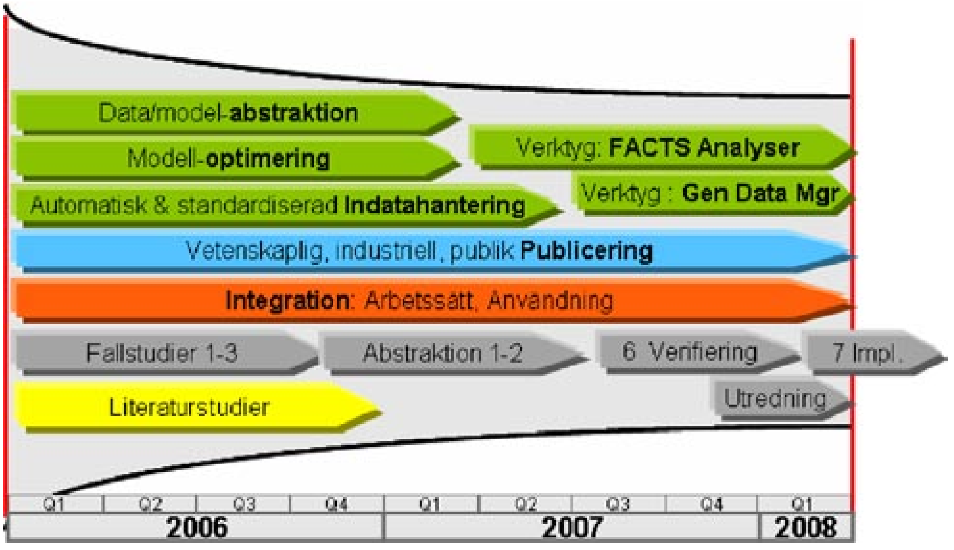

Figure 5. Project plan: Research and development work, publications, and integration work was based on empirical results from successive case studies.

Abstraction of Models

Modelling means making simplified representations of reality – the work on abstraction in this project concerns methods and tools that support making the right simplifications, without introducing too many restrictions and fallacies in the model. The abstract model can support tests of alternative plant concepts, despite a high level of uncertainty, in order to support rapidly changing pre-requisites. The research task is to test, develop and implement a number of theoretical methods to a collection of systematic and industrially applicable methods.

Input Data Management

When production flows are analysed using discrete event simulation there generally is a lot of data available, e.g. control logic, production orders, product mix, and buffer sizes. All must be gathered, but also interpreted, presented, and calculated to fit models, both software, and human users. This means, the availability of data that is directly useful for simulation analyses, is in practice low. Therefore, when analysing a factory system, the time spent on managing input data is really out of proportion. The research task is to make information management efficient in early project phases, and thereby provide the prerequisites for factory concept analyses. Efficient tools and methods for measuring and analysing production data is also developed, to facilitate data management.

Finding the Optimal Solution of a Model

When analyzing factories the best solution is to be identified, i.e. the best combination of values of all the parameters that can be manipulated, e.g. capacity, operators, flow logic, or buffer sizes. A common difficulty is that there is a high amount of (often conflicting) parameters to analyse. Often one of the parameters is modified at a time, or an experimental plan is followed in order to iterate to the best solution. The research task is to develop a simulation-based optimization that automates the search. Even when there are a great number of parameters, this method would easily find an optimal solution. Possible combinations of values of all the parameters are evaluated in a systematic manner to find optimum, using artificial and intelligent methods. The advantages by using this method, is that better solutions will generally be found, as compared to manual search. Also, a lot of time is also saved since the manual optimization procedure is very time-consuming.

Case studies

All project's deliverables were aimed at being implemented in participating companies' industrial environment. As a necessary base for the research and development work, the project gathered empirical data from a number of case studies, which were carried out and evaluated successively during the project. Seven case studies have been conducted at Volvo Cars in Göteborg, Volvo Trucks (Umeå & Tuve, Göteborg) and Volvo Powertrain in Skövde. In two studies, detailed models and abstract models were developed to be compared and to evaluate abstraction methods. Other case studies have focused input data management, data objects, interfaces, and statistical functions. Finally, some studies aimed at verification, evaluation of usability and implementation of results.

Project outcomes

FACTS has achieved its objectives, providing support for facts-based decisions in early phases.

Through the used methods and tools, "frontloading" the use of virtual methods for analusis of complete plants is achieved.

More Precise, frequent and quicker analyses

Main industrial goals are to make simulation analyses more frequent, quicker, and more precise:

- *More Frequent:* 50 % more analyses in the conceptual development phase, i.e. "Frontloading". This is difficult to verify since the implementation at the partner companies are in progress 2008. The shorter modelling time achieved (se below) also will make possible more frequent analyses.

- *Quicker*: Reduce the time required to conduct simulation projects by 20 %. This has been verified by project case studies, by using FACTS Analyser and GDM-Tool. At least 50 % reduction of simulation project time, 75 % reduction of model building time, 50 % reduction of input data handling time of model, and 50 % experimentation time reduction. A simulation model at Volvo Cars that took four weeks to build using commercial package, took only 40 minutes to build using FACTS analyser.
- *More Precise*: Increased precision of the simulated capability of factory systems. This goal was achieved using simulation based optimisation. Traditionally optimization is not used as a consequence of the complexity of the systems. The simplicity and efficiency of FACTS Analyser make optimization feasible also for conceptual analyses.

Widespread usage of the tools

The ease-of-use and the speed of the software make it possible also for production engineers to use, also in smaller companies with lack of previous simulation experience and resources. An advantage is the predefined modules for e.g. kanban control.

The FACTS Analyser could be used for conceptual analyses to identify bottleneck, suggest improvements, and buffer design. The software could however be used also in later program stages as well as in operative production. It could be a fine tool to visualise and communicate ideas internally or externally with sub-contractors.

FACTS Analyser is in itself very generic –all companies, regardless of size, having discrete production could benefit from using it. Companies with line production and having frequent changes, will benefit most. As compared to traditional simulation packages there is a significant reduced need for education.

GDM-Tool does not require powerful computer recourses, as do FACTS Analyser. GDM-Tool could be used in conjunction with FACTS Analyser but also work well as a complement to commercial simulation packages. Today approximately one third of the time is spent on data input management – this time is reduced significantly using GDM Tool. Thereby, simulation can be used more frequently and earlier.

Collaboration

The FACTS project was conducted in close collaboration among all partners based on a series of case studies. The approach has been very successful and productive. The project has also collaborated with National Institute of Standard and Technology (NIST) in USA, mostly regarding input data management and the CMSD standard. Several representatives from NIST have visited the research group in Sweden and two researches from FACTS have been working at NIST for the project.

Participating parties and Contact person

In the project, around 20 persons have been working, of which 11 persons represents industry. If you need further information, please contact:

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Mats Jägstam	Högskolan i Skövde	mats.jagstam@his.se
Björn Johansson	Chalmers tekniska högskloa	bjorn.johansson@chalmers.se
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Interactive Computer based Training and Process feedback (ICT-P)

How can launches of new vehicles in production be supported by computer based training of operators? Which learning models are applicable and what way of learning is best for computer based training? Can computer based training affect quality output? How can computer based training be designed to best support standardized work? How can operators and team leaders be supported better in continuous improvement processes and feed back of experiences back to the organization to avoid repeated problems and mistakes? These questions have been investigated in the MERA project Interactive Computer based Training and Process feedback (ICT-P).

Swedish vehicle industry has a favorable position in comparison to many of its competitors regarding education level and based on this the project has focused on opportunities for being more competitive by using computer based technologies in new ways also down on the shop floor level.

Results from several case studies accomplished in existing automotive production has constituted the base for developed methods in efficient Computer based Training and Process feedback.

Objective

The overall objective in the project has been to develop efficient methods regarding usage of computer based tools for learning and process feed back within the production organization. The objective has also been to give a higher flexibility in the organization regarding increased number of variants, with stable or improved quality output. By introducing new operator training methods can this be more efficient, start earlier and be more flexible. Important will be to utilize computer technology to give better conditions for faster introductions of new vehicle models and also gather process experience and knowledge in a way that will improve quality output

Research areas in focus have been applied learning during vehicle launches and knowledge transfer and management in production related issues.

Results and deliverables

The project has been divided in two major parts

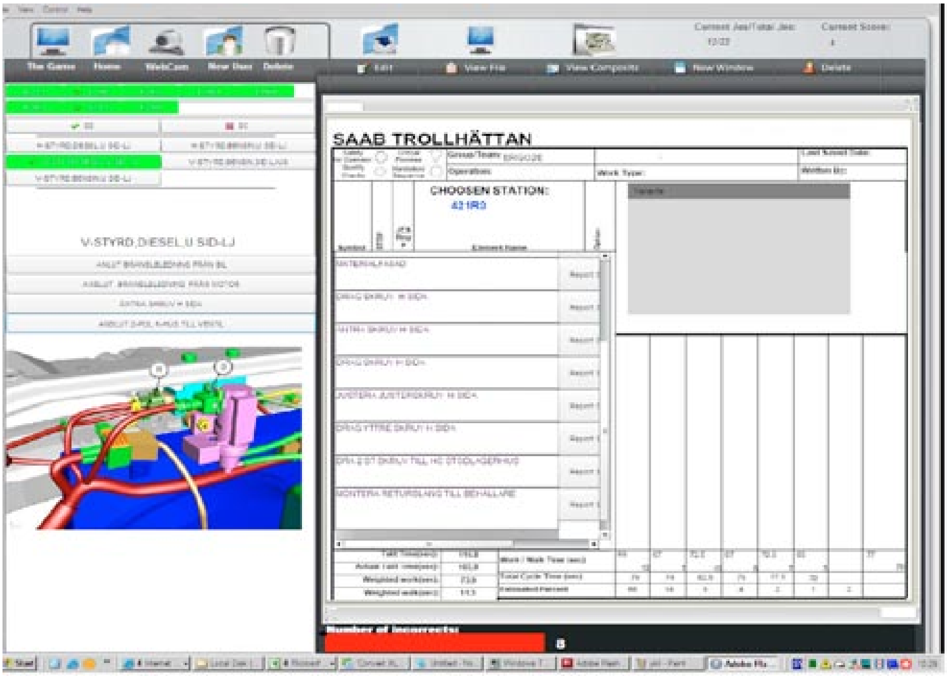
Project part A: Learning in operator role

The goals in this part have been to identify of key parameters and prerequisites for efficient job training of operators. Methods for efficient job training have been developed through several case studies, all accomplished in different production areas in an assembly plant. The results have been documented in several papers

The basic content in these are:

- A frame work which describes knowledge phases in operator training of new operations. The frame work can also be seen as a base for design of computer based applications within this specific area
- A model describing how new vehicle launches can be supported by computer based training. The model has two major parts:
  a) Preparatory computer based training (product familiarity) as a support prior to on the job training during pre series production
  b) Additional computer based training with focus on training of assembly sequences for different variants and quality issues connected to specific operations. This type of training has is only applicable when basic knowledge in performance of the new operations exists. Consequently this type of training is only useful in late pre series stages or during line speed changes. In the latter case a majority of the operations is known by the operators but new operation sequences must be trained.
- The two parts in the model have been evaluated in several case studies and the results are positive regarding operator opinions, integration level with existing training methods and quality output. The latter was shown specifically in a case study where the quality improvements were about 15 % compared to the reference group. All case studies have been documented in conference proceedings and in some cases also journal papers.

In the computer based training part regarding sequence training and quality issues new training software was developed. This software was used in the case studies. The software (fig 1) utilizes already existing process document information stored in a database. Re-use of already existing information has made it possible to perform training with a minimum of preparation effort.



Figur 1. User interface from the new developed software, used for sequence-and quality training.

Project part B: Learning by process feedback

The goals in this part have been focused on key parameters and prerequisites for efficient knowledge transfer within and in interaction with the production organization. The base for this work has been studies of existing processes and from that develop models for management of experiences, problems identified in production process, problems related to running changes etc. and how these issues can be treated and documented. The project part has initially studied knowledge transfer between different parts in organizations. Connected to this activity a case study was accomplished with focus on information transfer and processes in running changes. This was followed up with a questionnaire survey in cooperation with another MERA project, DLP-E. This study included Volvo Aero and Saab Automobile which were compared regarding knowledge transfer and information flow connected to production experience. The result shows for both companies that processes to reduce repeated problems in production are limited or missing.

This project part has further activities planned and the final part of the project will be spent on problem solution processes connected to continuous improvement activities. Detailed analyses in existing processes will constitute the base for an improved problem solution process combined with an improved coaching model to better support the operators.

From an academic viewpoint the project had, the goal to contribute to the generation of two doctoral degrees. One of the PhD students has ended the employment and consequently will this goal not be fulfilled. The other PhD student will present a licentiate treatise in the time frame of project end. That is after about three years from admittance to the doctoral studies. This is a comparatively short period for an industrial Ph.D. student.

Project realization

The project with end in December 2008 has been performed as a research project where two PhD students were linked to the project. One of them being employed by the industrial partner (Saab Automobile) and one employed by and affiliated to the universities (University West and Chalmers). The latter ended unfortunately the employment in Dec 2007.

Literature reviews combined with several empirical studies have been performed with aim to define and verify methods and work processes. In the studies of operator training rented software has been used during the whole project period. In some of the studies also external recourses have been used for preparation work. The studies have involved a large number of test subjects from SAAB Automobile such as assembly operators, manufacturing engineers and industrial engineers.

In project part A "Learning in operator role" studies have been performed in situations where operator job training has been a part of planned activities in the company. New product launches in the plant and changes in line speed rate have been used in the empirical studies. Main focus in this project part has been to identify necessary prerequisites for using virtual methods and processes as a substitute or complement to physical components and vehicles in the cognition dominated part of the training.

In project part B "Learning by process feedback" case studies, questionnaires and interview studies have been accomplished. Main focus has been placed on understanding of existing methods and work processes and, with this understanding as a base, develop models which describe more efficient problem solving and process feed back.

During the project period the PhD students' work has been supported by four master and bachelor level theses.

Project outcomes

From an industrial point of view the project with its conducted activities has shown examples regarding positive effects that can be achieved through computer based training. The case studies have shown:

a) Positive quality output from computer based trained operators vs. a reference group

b) A positive insight regarding strength in usage of 3D information as a pedagogic tool during launches of new vehicles
c) A positive interest regarding usage of computer based training within SAAB Automobile but also within GM/GME.

Discussions regarding deployment of this type of training are ongoing but no decisions have been taken.

Results and knowledge dissemination:

Project presentations:
MERA Assembly cluster meeting, 10 Oct 2006.
Vinnova MERA conference, Feb. 2007
Visual Forum, conference, April 2008 in Göteborg

Lectures in university courses:
Virtual Production, Chalmers, Dec 2006
Human Factors in Production, May 2006 and May 2007
Production Ergonomics, University West, May 2008
Ph.D. course for physicians in "Simulation and Virtual Training in Clinical Medicine" Sahlgrenska University Hospital, May 2007

Industrial contacts/visitors at SAAB Automobile:
GM Europe/GM North America/ GM Australia – approx 20 visitors during project period
Volvo Aero
Volvo Cars
Volvo Trucks
Scania (Oskarshamn)

Publications:
Journal papers: 1
Conference proceedings: 6
Master and bachelor theses: 4

Participating partners and contact persons

Saab Automobile AB	Lennart Malmsköld (project leader)
Innovatum AB	Lennart Walldén
University West	Lars Svensson
Chalmers University of Technology	Roland Örtengren

Contact person: Lennart Malmsköld, lennart.malmskold@se.saab.com
Phone: +46-520-84105

Concept development

Development of the Competitiveness of Saab Automobiles production in Sweden, domain IV

In order for Saab Automobile's production and development to continue in Trollhättan production technology and development processes must be world class in order to compete in the increasingly difficult competitiveness globalization brings. This requires initially quick and effective development which lies within the motive for MERA programs formation. In order to achieve this a number of smaller sub-projects have been completed within Domain IV 'Strategies, principles and methods for manufacturing – concept development'.

Objective

This project is composed of a number of sub-projects directed towards improved work methods which are the basis for rationalization and increased effectiveness.

Project realization and results

The project is composed of seven sub-projects

D.IV-1 MERA program administration

The purpose was to secure sufficient resources in order to develop the MERA program to its fullest potential as defined by the level of Saab in-kind investment in MERA projects.

The main outcome from this activity is that Saab Automobile now has responsibility for advanced manufacturing within GM Europe and has built up a dedicated group to this purpose.

This new responsibility yields an even greater potential to take on global GM responsibilities.

We have built up a network with our MERA partners and universities to an extent much greater than has existed at Saab previously which can lead to global competitive positioning for all parties.

D.IV-2 Process Development for "Dimensional Technical Specification"

The result of this project is a process where necessary process steps needed to create a DTS are identified, described and defined on a time scale. This was done by collecting the experience from earlier projects and applying them against new requirements such as reduced lead time and reduced hardware builds. Saab took a leading roll in developing this process which has now been rolled out within GM Europe.

D.IV-3 Development of Cross-Functional Work Methods for Increased Productivity

The purpose of this sub-project is to achieve a cross-functional work methodology and thereby increase the rate of improvement.

The project has resulted in:

- A standardized and documented process for increasing productivity
- 722 product cost reduction ideas where 381 were implemented for a total reduction of direct time per car of 57.3 minutes.
- Work method implemented on a European level.

D.IV-4 Development of Process Driven Product Development

This sub-project aims to evaluate a work methodology based on use of 'concept sheets' in communicating process requirements to those responsible for product development.

The project included:

- Formation of a cross-functional project group
- Suggestion of a standardized and documented process
- Suggested product changes for improved manufacturability

The project achieved:

- 12 people experienced with use of 'concept sheets'
- 25 unique requirements which were communicated and eventually approved of both product and process responsible members of the cross-functional group.

D.IV-5 Interior design development focused on reducing squeaks & rattles and assembly time

This project has developed a better objective requirement setting for squeaks and rattle. With improved objective requirements, simulation can be done in a early project stage and product design can achieve the requirements already in a virtual environment. In order to define better requirements the project has used the objective data in

JD Powers analysis and defined a number of vehicles which are both good and poor from the instrument panel. These vehicles are amongst others: BMW, Audi, Lexus, and Saab products. On these vehicles we have completed exhaustive competitive analysis in order to understand how these instrument panels were assembled, how they were designed structurally, as well as completed structural dynamic testing to define their objective performance.

The project resulted in a number of different objective requirements for an interior sub-assembly (instrument panel) which can be validated via virtual methods (finite element analysis) and experimental structural dynamics.

Furthermore, through virtual methods design changes can be identified to reduce the number of late fixes for squeaks and rattles in production.

D.IV-6 Implementation of MTM-UAS for time analysis

The purpose of this sub-project is to implement MTM-UAS for time analysis and use the same criteria to calculate the time to produce vehicles in Trollhättan as well as for vehicles produced in other GM European factories. In this way we can compare apples to apples and show how other processes in this project result in significant improvements and thereby improve our competitive situation. BEC (Base Engineering Content) is the basis for time measurement in the car industry. BEC is the time needed for an operation which creates value added for the company the operator is employed by.

A total of 15 people have been trained to different levels in the systems, thus creating an extensive competence in the field. Further, an evaluation has been done, whether or not IGRIP's MTM module can be used to generate MTM time in virtual evaluations of ergonomic or accessibility situations.

D.IV-7 Implementation of Production Documentation System

Production documentation is information necessary for a factory to produce vehicles. The Production documentation system is a system which compiles this information and where a person can collect and generate all necessary information. Other IT-systems which are used at Saab are for example systems for product data, changes, production planning, vehicle classification and from these there is an opportunity to automatically create connections to the production documentation system.

The project has resulted in Saab Automobile in Trollhättan having implemented a new production documentation system, PIM/APS, which raises the competitiveness with respect to development and production of global and new projects/platforms within GM.

Through this project we have achieved the following:

- Standardized development process of production data
- Higher quality level of production data
- More effective use of production data
- Basis from which development of global projects can be completed.

D.IV-8 Implementation of a Process Planning Tool

In manufacturing engineering work a large number of different digital tools are used and documentation occurs in various different systems. Through collection of all this in a single digital tool a huge advantage can be achieved in shorter lead times, reduced resource needs as well as reduced risk for mistakes. Furthermore, the ability to handle complexity induced by increased product variants is raised.

This sub-project includes as a first step implementation of such a tool at Saab and training of the necessary manufacturing engineers. The result of this was implementation of the system and training of 18 people having a basic competence in the system.

The planned subsequent step to develop the systems potential with respect to accessibility simulation was moved to the separate MERA project ”Virtual Geometry Assurance, Path Planning & Station Logic”.

Project outcomes

The breadth of this project is such that all parts of production and manufacturing engineering organization at Saab has participated in some form or manner. This has produced results in the form of improved productivity via an improvement in HPV (hours per vehicle) which has gained significant attention within GM. Furthermore, has Saab’s increased competence been requested within the GM global organization.

Participating parties and Contact person

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Lean Production

The pedal go-cart factory – Lean management in practice

Objective

The objective is to enhance the competitive strength among Swedish supplier companies by means of knowledge and training in the field of Lean production. The project primarily aims at education and training of top and middle level management in the companies. Each manager trains and coaches his closest co-workers. This project aims at taking Lean Production to a higher level, to establish genuine understanding and to make way for sustainable change in the companies involved

Results

The project resulted in a training program, Lean Management, which will take place in a special training facility," Trampbilsfabriken". This training gives in a very firm manner, prerequisites for a successful implementation of Lean Production. The essential difference between this training program amongst other types of training is the high amount of practical work, both in the training camp, and in the own company between the training sessions. The education in the pedal go-cart factory provides training for top and middle level managers on how to act as leaders and on how to accomplish lasting and continuous improvement within their companies. During the pilot training program this has shown to be very successful.

– *"I've learned two things; the importance of to keep things in order in the production, and also to minimize the waste of time".* (Fredrik Revellé, Ferroprodukter)

Lean Management – training sections

Project realization

Training structure

In the first part of the project were other similar training courses investigated, and we found that the most successful trainings were those who had practical parts in the training. The experience of the project team members, were also that a lot of practical training is necessary for a good result. We also found that the trainings were a smorgasbord of methods and tools, without structure and context.

In order to achieve a sustainable improvement work, we developed a practical training program divided into sections, where the structure of the sections follows a generic process that have been used in Japan for more than fifty years. From the beginning this program were divided in six training occasions, comprising two to five days per section.

Later on this was revised, because of the difficulty to get the managing people to stay out of the company for more than two or three days. Then we decided to have six occasions, comprising two days of training.

The practical training provides know-how in terms of lean-methods and continuous improvement, and how to manage and drive a lean organization from a manager perspective.

In the sections the participants will face problems, get support on how to solve them, and later work with these questions at home. The homework will be shown in the next section and will be followed up by a study visit, where the participants can share other companies' experiences and solutions.

The idea behind the plan is to make way for rapid application of this know-how in each of the participants' businesses. The practical training of top and middle level management is carried out by Japanese trainers (industrial engineers and senior managers) along with experienced consultants, in order to provide a unique leadership training that goes far beyond what is offered in Swedish trade and industry today. In addition, managers from Swedish car manufacturers will participate as trainers.

Trampbilsfabriken

Trampbilsfabriken is a neutral production environment (a pedal go-cart factory) which is developed for lean management training of people in top management positions. The aim has been to develop a flexible production environment, where the participants will develop the factory from the original state, "Swedish industry standard", to a factory which is world-class.

The participants are tempted to find improvements without major investments, for example will assembly fixtures be made of used cardboards, which easily ca be rebuilt and improved by the students themselves. The motto is; "Use your head, instead of your money". Trampbilsfabriken gives the managers possibilities to face problems, learn from their mistakes and try out different improvements in a neutral arena. They will be supported by the trainers in the implementation of the improvements.

Homework and coaching

An important part of the training is the homework between the training sessions. Before the training, each participating company points out a pilot area, where the homework should be done during the training. The participants will then have to train the people who works in the pilot are, using the train-the-trainer principle. The homework is connected to each section, and the managers are supported by, coaching days, where the trainers visit the company. The pilot area will be developed and improved in this way during the training program. In the next section all homework is shown, and that is an important part as it gives the possibility of learning and experience sharing between the participating companies.

Study visits

Study visits are an important part of the training program structure. These visits are focused on the previous section and homework. The participants can ask questions about specific problems, and share experiences and solutions with the host company.

Sequel of the project

Innovatum will give this training with funding from NUTEK during the years 2008 to 2010.

Project outcomes

The main outcomes of this project is the following:

- An internationally and nationally recognized arena for Lean training
- A totally new and very successful concept for Lean training
- Possibility for Swedish subcontractors to get a rapid start with the implementation of Lean, and by that means strength their competitiveness
- Possibility for managing people to learn how to achieve Lean improvements, without disturbing the company's production environment
- Possibility for leaders to train their own people in a neutral environment
- The companies that participated in the pilot training, achieved a very high level of improvements during the training

Participating parties and Contact person

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Bo Bergman

Linköpings Universitet
Jan Olhager

How you break a mass production culture in a company and introduce Lean production

Objective

The over-reaching goal with the project is to create a model that can offer Swedish companies guidance in how they can create a secure and effective Lean Production from a mass-production starting-point. Through the cooperation between companies, research institutions and unions a ”See model” has been produced which will serve as a benchmark for the Swedish manufacturing industry and educational institutions.

Results and deliverables

Practical changes in work procedures

Practical changes in work procedures were performed at both Cabeco and IAC. An example of performed changes at IAC (Scania cell) is accounted for in figure 1.

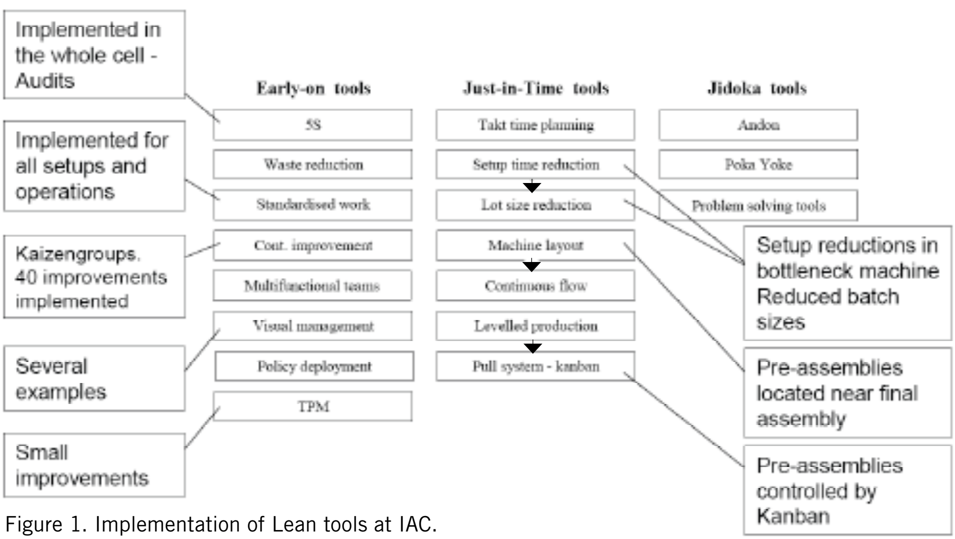

Figure 1. Implementation of Lean tools at IAC.

Studies of the planning system

In this part of the project changes were observed in the companies planning systems when Lean philosophies and Lean tools were introduced. The purpose was to identify necessary changes in the companies planning systems during a development towards a more Lean production. The aim was further to identify possible hindrances within the planning systems towards such a development. The planning system includes a number of components that can be influenced. See figure 2.

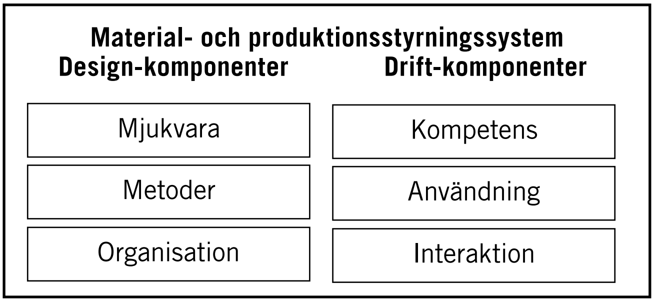

Figure 2. The components of the planning system

In the beginning stages of the project an extensive literature study was performed regarding Lean principles, Lean tools and the implementation of Lean. A model of necessary Lean tools, Lean principles and their implementation order was put forward based on this study, which is shown in figure 1. This model was then used for analysis purposes in the two case companies' Lean transition projects. During the practical implementation stages of the project it was continuously observed how the companies planning systems were influenced by the changes made in their planning environments.

The implementation of 5S and a standardized work had no visible effect on the planning systems in either of the two companies. On the other hand, the planning systems were influenced in many ways through the implementation of visual management in both case companies. The largest influence was on the organisation of the planning in terms of the decentralization of planning and information steering to the teams. The introduction of improvement groups had in themselves no influence on the planning system, it was rather influenced by many of the performed improvements.

At IAC the introduction of a pull system in the pre-assembly stations had many other effects on the planning system. The practice of the planning system was changed. On the one hand the bills of materials were made flatter when the pre-assembly processes were removed from the bills of material. On the other hand, backflushing was introduced. The introduction of a pull-system also influenced the organisation of the planning since planning activities were moved from the central planner to the operators.

Studies of the change process

In the beginning stages of the project a literature study was performed regarding Lean principles and strategies for organizational change as well as consequences of the introduction of the production concept according to Lean. At the same time a survey was carried out in the two companies, with questions measuring the psychosocial work environment, the attitudes towards change and expectations of how the introduction of Lean production would impact the work conditions for each company. During the course of the project the transitional process was monitored in repeated interviews with key persons.

The driving forces when it comes to changing a work environment can be both external and internal and illuminate *why* a change has to be performed. For an effective change to occur both the ability to improve the result on a short-term basis and to use the possibility of investment for long-term competitiveness have to occur. Short-term changes can for example be found in lead time and quality improvements while long term improvements also demand that the employees' work conditions and competence are developed. The prerequisite for a successful change is therefore dependent upon both *what* has changed and *how* the change has been performed.

In both companies the customers' Lean work has served as a source of inspiration but the changeover had mainly external driving forces. Therefore it was clear in parts of the companies of *why* a transition towards Lean production had to be done.

The question of *what* had to be changed was initially about what kinds of Lean tools had to be implemented in each company (see Figure 1). When the first year of the project was completed, a need for deepened knowledge about the Lean production philosophy was raised. At Cabeco the company's management group performed a work shop about change in leadership habits and Lean production philosophy. Through a Lean assessment in 2007, IAC also became aware of the need of a production philosophy and as a result of this the management group attended a Lean production course at Chalmers University.

The question of *how* the transition was going to be performed was raised on several occasions during the process. At IAC a lot of time was spent in order to anchor the change in work procedures at the highest management level in order to assure the awareness and continuity. On the initiative of the highest management a number of Lean tools were introduced into the Scania cell project. The project was initiated in an ordinary project manner.

In order to establish a more active commitment amongst the involved persons in production, educational seminars and workshops were held at the same time as the work in the improvement groups was started up. The improvement groups were highly committed to the task.

During the first year of the work towards a more Lean production, great alterations occurred at IAC. The company came under new ownership. A new Plant Manager was hired and he performed a re-organization that resulted in lay-offs. The conditions for a continued Lean project were highly limited at that time.

At the same time as the basic conditions for the Lean work had been changed, a certain amount of process control had been maintained by a few key persons. During the second part of 2007, the new organization of IAC was stabilized. This lead to a renewed interest and involvement in the Lean work. The project was described in positive terms, but at the same time there was a realization that much work still had to be done.

At Cabeco as well, the work toward Lean production was initiated through the implementation of a number of Lean tools. During the first half of the second year of the change process towards Lean production there were noticeable results of the Lean work. This seemed to primarily be the effect of that improvement groups had started up. At the same time a new Operations Manager with Lean Production experience was recruited into the organization. This meant a strengthening of resources in the work towards Lean.

In September of 2007 a decision was made about out-sourcing Cabeco´s production. At the same time interviews were performed with the employees of Cabeco. Despite the difficult circumstances, several persons voiced that the Lean work had had positive effects on the working conditions in the company – this in a company with a very good psychosocial working environment from the onset of the project.

Project realization

The following surveys and practical changes in work procedures were performed during the project phase:

1. Through the practical transition phase, several fundamental Lean principles and Lean tools were introduced into the companies' value streams.
2. A study of the planning system's limitations and possibilities during a practical change from a mass production perspective to a concept based on the fundamentals of Lean production principles was performed.
3. A study of the realization of the transitional project with regards to how the individual's involvement, ability to change and work situation were influenced by the transitional process and vice versa was performed.

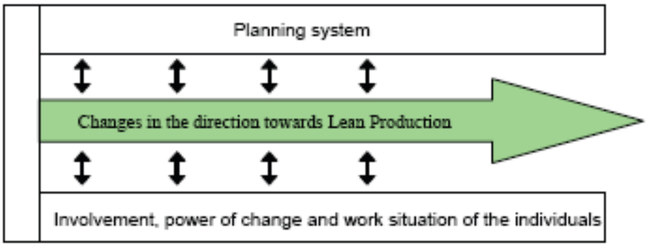

Figure 3. Schematics of the three project parts.

Project outcomes

The transition process towards Lean

The effect became a ”See model” at IAC which is used for benchmarking purposes internally and which is also available for the Swedish manufacturing industry and educational institutions.

The planning process

Based on the experiences of the two companies in the case study, it can be concluded that in an early stage of a Lean implementation; i.e. with the introduction of early Lean tools (early-on tools), it is above all the *organisation* of the planning and *practice* of the planning system that change. *Methods* for planning and steering are primarily modified when the implementation has continued for a certain amount of time, i.e. when later tools (Just-in-Time tools) are introduced.

In the two companies in the case study it was observed that the introduction of certain Lean tools, e.g. a pull system, resulted in changes in both the planning systems' *design- and operational components*. Some of the early-on tools such as 5S and a standardized work did not influence the planning system. Other early-on tools such as visual management lead only to minor changes of the planning system's *operational* components.

None of the implemented Lean tools in the two companies in the case study resulted in changes in the planning system's *software*, but since the implementation is still in an early stage in the two case study companies, additional changes of the planning system will occur, possibly also in the *software*.

It seems as if the early implemented tools (early-on tools) have less of an influence on the planning system than tools that are implemented later (Just-in-Time tools). That is why it is safe to assume that a company's existing planning system doesn't serve as an obstacle for a Lean implementation. Much can be done to minimize waste and improve the value streams, i.e. an introduction of 5S, standardized work procedures and before there is a need to make any major changes to any of the components of the planning system.

The change process

The experiences of the change process both at Cabeco and IAC demonstrate the importance of all affected parties involvement in the processes to contribute to the development. The following lessons can be learned from the change process towards Lean production:

- Create forums for a continued dialog about targets
- Create a broad understanding and participation among the involved employees, to support and encourage experiments
- Create a balance between action and understanding
- Involve company management – they have to take an active interest and participate in the process. This is the case for both higher and middle management
- Be attentive to changing circumstances

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by funding needs-driven research
and developing effective innovation systems

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