SIMET Geometrical Inspection and Control Planning

Klassad Risk

	Möjliga Poäng	1	3	9	10	30	100	300	1000	
	Nivå	LÅG		MEDEL		HÖG				
Mätbehov	Processtyrning i maskin	1 Mätinstruktion		2 VSK CPK 1,33		3 VSK CPK 1,67				JA (Styrbarhet i produktion)
Mätbehov	Processkontroll i mätrum	4 Mätprotokoll		5 CPK 1,33		6 CPK 1,67				JA (Styrbarhet i produktion)
Mätbehov	Processuppföljning Ej behov	8 Vid Behov		7 Processuppföljning mätrum (artikelrevision)						JA (Styrbarhet i produktion)
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Mätbehov	Processuppföljning Ej behov	8 Vid Behov		7 Processuppföljning mätrum (artikelrevision)						NEJ (Styrbarhet i produktion)

Mättyp

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1. Summary

SIMET GICP has been a very successful research project and has resulted in a task model for the systematic measurement technology planning and preparation. QSM, the quality assurance matrix, has been implemented as a tool and method in the case studies at the participating companies. Also, QSM has been further developed and improved by logging the improvements that were continuously identified.
The QSM approach has been evaluated and is now planned to be introduced in Scania and Saab Aerostructures in Linköping. At Scania QSM is even considered to become a global Scania standard, and that is a great recognition of the QSM approach and methodology introduced to Scania by this project. As of today QSM has been developed and implemented with significant success at Volvo CE in Eskilstuna. One reflection though is that it Volvo CE needs to be persistent with the operation and the methodology to ensure that it is maintained and developed. The method and approach need to be casted into the training of their employees to keep the skill up to date with the QSM method and approach.
The SIMET - GICP project has involved leading scientists at NIST (National Institute of Standards and Technology) in the U.S., who have been co-authoring one of the articles that was included in the licentiate thesis. It is the international standardization project QIF (Quality Information Framework) run by NIST, that discovered our research in the SIMET - GICP project.
PhD student Richard Lindqvist has been appointed technical specialist in the field of production engineering metrology at Saab Aeronautics in Linköping, as a consequence of the project’s success.

2. Background

The manufacturing industry needs a standardized approach to support technology development that will carry out improvements to reduce scrap rate and increase productivity in manufacturing. As part of the SIMET GICP research project, four manufacturing companies, Scania, Volvo CE, Saab and Leax joined the project to develop a standardized approach for measurement and control planning. The reason for this is that the performed measurement preparation is often far too late in the development process. This leads to increased costs and customized solutions. A standardized approach for measuring and control planning is assumed to lead to both reduced interference and less scrap and costs by preparing the work in a systematic and streamlined way.
Sörqvist reported already in 1998 in his doctoral thesis that the cost of quality deficiencies amounted to between 10-40 % of a company's annual turnover and this is the result recognized directly at the end of line at the end report. [1] In recent studies Sörqvist reports that quality costs usually fall between 10-30% of the annual turnover of a

company.[2] The model based on QSM and its supporting tools will help in the determination of appropriate measurement and inspection frequencies, the measurement procedures and other activities that lead to quality and geometry assurance of the machining processes.

3. Aim of project

The purpose of SIMET GICP was to develop a productive and sustainable framework based on the recently developed methodology for geometric measurement and control processing in manufacturing of complex products and components. The result is reflected in the more efficient utilization of metrology resources by classifying the needs of measurement and let the design department take note of how effective measurements are made in the workshop.

4. Implementation

The research on systematic measurement/inspection and control planning, aiming for a reduction of the cost of poor quality in Swedish industrial companies, has mainly been conducted in four companies. It is Volvo CE in Eskilstuna, Scania CV in Södertälje, Leax in Falun and Saab Aerostructures in Linköping. Thus, the research was not solely focused on the automotive industry as Saab Aerostructures participated in the project. With Saab Aerostructures involvement a spin-off effect into the aerospace industry happened and similarly a feed-back to the automotive industry from Saab became apparent as an interchange of information and knowledge could be transferred as part of the research project SIMET-GICP.

The used activity model, methods and procedures for systematic measurement planning and preparation has been generalized as far as possible, although there are subtle differences between the automotive and aerospace industry's way of working through the application of technical specifications and governing standards in their respective fields. For example, the automotive supply industry has to comply with ISO/TS 16949 which contains; APQP - Advanced Product and Quality Planning, PPAP Production Part Approval Process, process control plan and measurement systems analysis (MSA). Similarly the airline manufacturing industry is controlled by AS/EN 9102 First Article Inspection (FAI) and AS/EN 9103 Variation Management of Key Characteristics (VMKC) and its documentation requirements on measurements, monitoring, control and surveillance of so-called KC (Key Characteristics) with a process control plan PCD - Process Control Document and, not least out of customer requirements.
The companies have supported the project in an exemplary manner and put in considerable resources to carry out the extensive case studies in the project.

The project started in January 2010 but was extended due parental leave / sickness absence and it ended 2013-12-18.

5. Results

5.1 Contributions to FFI-targets

Out of the 14 FFI goals listed below we can definitely check off 12 as being in compliance with SIMET GICP. These twelve are green-marked and fitted with a check mark.

- ✓ how well the project meets the goals defined in the transport, energy and environmental policies
- ✓ industry's possibility to perform knowledge-based production in a competitive way in Sweden
- ✓ contribute to continued competitive automotive industry in Sweden
- ✓ conduct industrially relevant development measures
- ✓ lead to industrial technology and skills
- contribute to security of employment, growth and strengthen R & D activities
- ✓ contribute to concrete production improvements made by participating companies
- ✓ strengthen research on selected and prioritized research in production engineering
- ✓ support research and innovation environments
- ✓ work to ensure that new knowledge is generated and implemented, and that the existing knowledge is implemented in industrial applications
- ✓ more efficient utilization of R & D results so that concrete production improvements are made by participating companies
- increase the quality of the production engineering education
- ✓ strengthen collaboration between the automotive industry and government agencies, universities and research institutes
- ✓ act to secure the national skills supply and establish R & D at a competitive high international level

5.2 Case studies at Scania, Södertälje and achieved results

In total 8 workshops and 16 workgroup meetings have been conducted during the project period. We've also tried to run the so-called pulse meetings over the Web by using Microsoft Lync and this has worked very well. Pulse-meetings over the Web have been a very good and cost effective way to get ahead in the project and capture all relevant issues. In addition, the pulse-meetings led to a continuous follow-up of the research and increased the awareness of the SIMET-GICP project. The project has been taken very seriously by Scania, and has been one of the prioritized projects.

Start-up meetings were conducted with a high frequency of various interest groups at Scania. Initially we focused on introducing Scania managers and engineers to the QSM tool (Quality Assurance matrix) and explain its principles and how to work with the tool. A mission statement was defined early in the startup phase of the project by the coordinators Anders Berglund and Niclas Josefsson, working at Scania production technology development, and the statement was accepted by the production engineering development manager Sven Hjelm. This was important from the anchor point of view, and a confirmation of that the project and plan was well entrenched within the organization and the participating departments.

The case studies were carried out on the D12 cylinder block manufacture line and split into two separate cases. In Case Study 1 we studied and observed geometric features of a specific operation in the manufacturing flow, operation 20, which is a rough milling operation. In Case Study 2 we studied, all critical properties throughout the process flow for the cylinder block manufacture. During the work with QSM the workgroup identified and logged strengths / flaws / weaknesses / opportunities with the QSM approach.

Two deliverables in the form of reports have been written. The first report describes the two performed case studies and has been reviewed and approved by Scania for publication. [3]

The first report describes the work and results of the two case studies where we used the QSM approach to analyze the geometric properties and its corresponding measurement and inspection frequencies.

So far we have seen that we have a good correlation between today's existing control rates with those calculated in the QSM matrix. But in some cases more frequent measurements are proposed, especially for those properties that have a high classification rating and relatively low Cpk values.

Suggestions for modified and new measurement and inspection frequencies are proposed, and hopefully these will be implemented in the planning process so that we can later verify its impact in the production. In addition, we have extracted capability index data from the Scania statistical process control database named Q-DAS. [4]. From these data we can conclude that Scania show Cpk > 2.0 in nearly 80% of the properties that we have studied. Thus, Scania can with a strong factual basis, reduce the measurements carried out in the local metrology rooms by about 80%. In the case of engine block line, two blocks are measured per day and each block has a lead in the test room of about 8 hours. Thus, Scania can make considerable measurement resources available in the test room for other kinds of priority measurements.

A Master thesis conducted by Daggenfelt and Gustafsson, [5], started up in early 2013 with the aim to produce a first edition of a general metrology planning process. In their report they first present a comprehensive and more transparent activity model which is then followed by a more detailed activity model. In the developed measurement activity model the QSM approach is included as a guide and methodology support. After the completion of the thesis the work within SIMET-GICP research at Scania has progressed towards refinement of the metrology planning process and activity model, and it will eventually be incorporated with and interact with Scania's already chosen activity model for Machining Process Planning (MPP). By that it will eventually turn into an internal global Scania standard for measurement and inspection planning.

As QSM as a method and approach has now been evaluated, anchored and accepted to become an established “good practice” in the Scania organization, they have decided to go on with further deployment and use of the method. Among other things, the QSM will now be used within the new (DP) engine block manufacturing unit and in gear manufacturing of (DX) shaft drivetrain line. This was decided by the Scania steering committee at the end of SIMET-GICP project. Hence the method will be implemented on the new DP engine block manufacturing, which is a completely new manufacturing line to be started up. This is a great opportunity because this will be the first time the QSM approach is fully utilized right from the start, and analyzes and conclusions from completed QSM's can be retrieved relatively quickly.

The second report, [6], discusses the principles and views of measuring technology in general and the ISO / TC 213 "Geometrical Product Specification and Verification" approach, rules, principles and definitions.

To sum up, our research has been well received at Scania and a proof of that is the almost 100% attendance of Scania representatives at our workgroup meetings, workshops, Lync meetings and steering committee meetings.

5.3 Case studies at Volvo CE, Eskilstuna, and achieved results

At the SIMET GICP start-up meeting with Volvo CE a number of questions were raised. Some of them are:

a) What is the most important output from the QSM and what decisions can be made from a well conducted QSM process?

b) How is QSM applied today and what other supporting/application tools are used?

c) Is there an existing measurement planning process presented and is it visualized in the business / project model? Or presented some other way?

d) Who are users today? How many users? How many are trained in QSM? Who operates QSM issues? What are the roles, responsibilities and powers?

e) How many QSM:s have been performed so far?

f) What results and benefits have been achieved to date with the introduction of QSM? What can be improved, what has been improved?

Response on the questions:

a) What is the most important output from the QSM and what decisions can be made from a well conducted QSM process?

1. Decisions on which measurements are required to be made in the metrology room and which can be measured at the machine tool.

2. Decision on measurement frequencies for different types of measurements.
3. Decisions on which properties are subject to capability (Cpk) follow-up and how they will be performed.
4. Decisions on which measurements in the machine that needs to be documented.
5. Decisions on control methods for controllable measures.
6. Decisions on how the running of a test series shall be made with respect to process characteristic properties.
7. Decisions on how to ensure low enough uncertainty in the measurements.

b) How is QSM applied today and what other supporting tools are used? Application tools?

Volvo CE in Eskilstuna uses a database solution called Prince and the QSM is integrated as a method support.

c) Is there an existing measurement planning process presented and is it visualized in the business / project model? Or presented some other way?

This is described in operational model cOMMon, (Common, Operational Management). The measurement planning process is designed as an activity model, and descriptions and instructions on What and How is associated with each sub-activity.

d) Who are users today? How many users? How many are trained in QSM? Who operates QSM issues? What are the roles, responsibilities and powers?

No answer. Sufficient documentation is lacking.

e) How many QSM:s have been performed so far?

In total, nearly 400 QSM are completed and documented in Excel. In the new QSM database Prince, another 100 QSM are registered and documented.

f) What results and benefits have been achieved to date with the introduction of QSM? What can be improved, what has been improved?

No answer. Sufficient documentation is lacking. See comments below.

Overall, we have basically managed to answer the questions a) through e) except d), but perhaps the most interesting question, f), we have not yet managed to answer. However, some insights have been achieved, which can be briefly reproduced here: By working with QSM more complete drawings have been submitted from the design unit, with more appropriate tolerances and measurement specifications and solutions. The understanding at the design unit has become much better regarding product design for manufacturing as well as for measuring. The design engineers can also see the benefits of QSM as a working method and as methodology support.

From the beginning, at the startup of the project, the idea was that the case study at Volvo CE would involve collecting the results and experiences of the QSM approach, based on analyzes and conclusions. Unfortunately, it has been difficult to answer some of the questions, according to the list of questions reproduced above. This is because it has been difficult to obtain concrete, valid information and documented facts. Therefore, it was decided almost immediately that the work had to take a slightly different approach. Thus, efforts were focused on expanding the theoretical part of the measurement planning and two proposals on interesting areas were launched for deeper analysis.

Areas and job titles for the two areas to study were: "Geometric quality assurance of manufacturing process" and "Extraction and filtration associated with length measurement." These two areas that we have studied are on their way to result in two articles to publish in a recognized engineering journal in measurement or quality. The first article describes the role of metrology and we expand the view of the metrology role in product development and production processes. We present measurement technology such as:

1. *A proactive role* where the measurement data is used to ensure both articles functional properties, as a basis for establishing requirements, and also to ensure that the selected manufacturing method continuously provide opportunities for controlling the desired quality level.

2. *A production management role*, where the measured data are used in running production to control the quality outcomes and articles measures.

3. *A follow-up role* where different types of measurements are performed to monitor the production performance.

In the second article we extend the concept and we are trying to convey a modern approach to the concept of uncertainty. Traditionally it has been almost exclusively focused on measurement uncertainty, but it has now been expanded to include other aspects of uncertainty.

From the traditional approach to just talk about measurement uncertainty we have expanded it to include the chain: function, specification and verification of Figure 1.

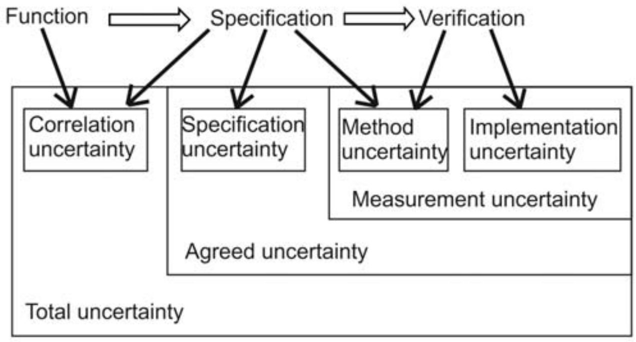

Fig. 1. Relation between function, specification, verification and the different uncertainties

To this chain we can couple various uncertainty concepts such as; Correlation Uncertainty that exists between feature and specification of a product or component. Specification uncertainty which is directly coupled to the specification tolerances. Method uncertainty is associated with both specification and verification. The so-called implementation uncertainty which may advantageously be collected and monitored with measurement systems analysis (MSA) or simpler GR & R (Gage Repeat Portability and

Reproducibilty) analyzes. All these make up a total uncertainty chain and all are linked with each other.

In conclusion, our research work has been well received at Volvo CE and it has especially been proved by the strong presence and participation at our working group meetings and workshops. A special thanks is addressed to Karl-Johan Karlsson, who worked as an industrial mentor and a very experienced metrology specialist for graduate student Richard Lindqvist.

5.4 Case studies at Leax, Falun, and achieved results

The efforts at Leax in Falun did not go as planned. It was hard to catch and conduct four case studies of four companies in four different counties at the same time and to find enough time to really do a good job. The response from Leax was initially low and has been reflected in the timesheets entries not given priority on their part. Unfortunately, therefore Leax was given lower priority in the project. However, an information and workgroup meeting was conducted where graduate student Richard Lindqvist received documentation from Leax, and was thus able to start up the work on a QSM matrix. The work focused on implementing this on the manufacturing of a hub reduction cap that Leax manufactures as a subcontracted supplier to Scania CV in Södertälje.

The main purpose of the case study at Leax was to obtain the subcontractor perspective which initially seemed important to try to understand and analyze. It is still a very interesting and important issue and should be investigated more thoroughly.

5.5 Case studies at Saab, Linköping, with achieved results

At Saab Aerostructures the research was focused on planning and implementation of a VMKC (Variation Management of Key Characteristics) program. This is associated with a development project, Boeing 787-9, and future production and installation of large cargo doors. A total of 57 information sessions, workgroup meetings mixed with workshops were conducted with the design, production, processing, utilities, planning and purchasing units at Saab. Early on, the possibility to identifying an appropriate use of the QSM approach was done. A project was started to develop an applied and adapted activity model to be incorporated with the development department at Saab. This activity model is essentially based on definitions and approaches drawn from the two governing flight standards, EN 9102:2006 FAI (First Article Inspection) as well as SS-EN 9103:2005 VMKC (Variation Management of Key Characteristics).

Workgroup meetings have been held with the two cross-functional groups working with carbon fiber composite manufacturing and assembly technologies. All disciplines such as design, production, processing, utilities, planning and buying have been actively participating in the project.

The QSM matrix concept and its related approach have been presented to a small workgroup within the Saab Aerostructures development department. An insight and observation is that the QSM template may need to be adapted and refined slightly to fit into the definitions and approaches taken from the two governing flight standards, EN 9102:2006 FAI as well as SS-EN 9103:2005 VMKC. A deficiency that has been identified at Saab is that today there is no explicit and written role definition for a measurement technician. Eventually, that role will be established and implemented within the Saab Aerostructures development and production organization. This is in agreement with the gained knowledge about the increasing demands of metrology expertice and industrial metrology with its increasing importance within the company.

Meanwhile, a major effort to develop a geometry assurance process has started at Saab Aeronautics and Saab Aerostructures as they have realized that measurement technology carries a central and important role. The goal of the SIMET-GICP project was ultimately to contribute with significant results and knowledge in the measurement planning processes and working with QSM. Both are important areas and components of a geometry assurance process and should thus be incorporated and harmonize to the larger and more comprehensive geometry assurance process, see figure 2.

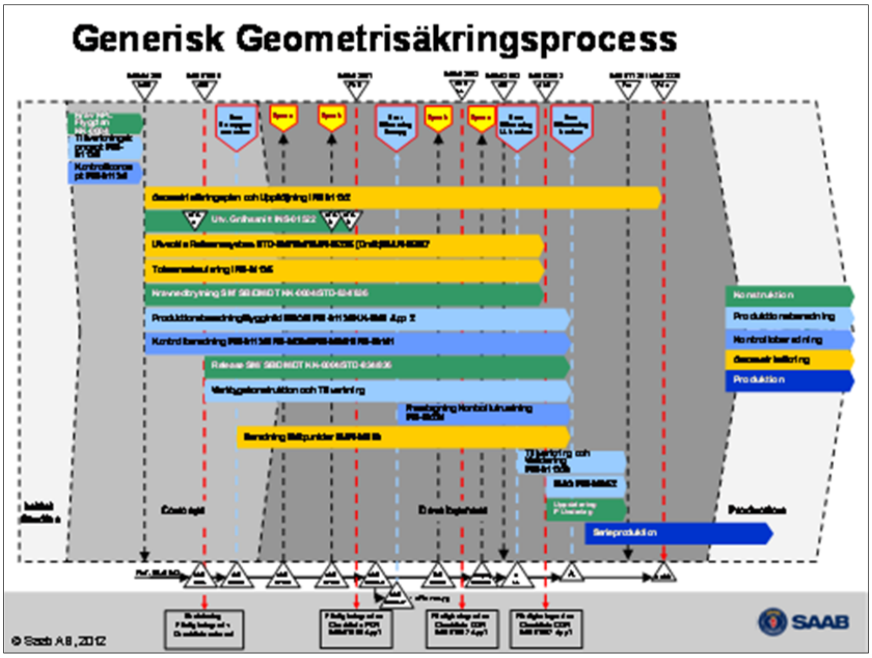

Fig. 2. Illustration of a generic geometry assurance process

6. Dissemination and publishing

6.1 Knowledge and dissemination beyond the meetings with the parties

International standardization work
In addition to the SIMET-GICP case studies we have participated in an international standardization project called QIF (Quality Information Framework), and have also been active in 10 workgroup meetings that were run over the Web. This has been an effective form of collaboration and has worked out very well so far.

PhD student Richard Lindqvist participated in a QIF (Quality Information Framework) standardization meeting in South Carolina, USA, on 11-15th of June 2012 [7].

Supervision of master thesis work
A master thesis work was started in 2013 and was tutored by the PhD student Richard Lindqvist. There were two students from KTH who chose to carry out their investigation at Volvo Cars, Torslanda in the field of robust design and tolerancing, [8]. They studied the quality costs, and in particular those costs that can be attributed to geometrical defects. Their working title was: "Geometrical Quality Failure". Their studies are important for SIMET-GICP research because measurement technology and production engineering measurements are mainly aimed at ensuring a centered target value, and be repeatable and reproducible through manufacture and assembly of components. Cost of poor quality and the quest to minimize these costs are good incentives for the use of systematically implemented production engineering metrology.

Planning and implementation of educational dissemination of QSM and measurement planning and control
Education in the SIMET GICP-field of production engineering metrology and measurement technology is today part of a lesson in the advanced level course MG2210 - "Advanced Metrology" at KTH. In addition to that, a modified course element is planned to be incorporated in a new undergraduate course MG2010, Modern industrial metrology, at KTH. In Eskilstuna a new education that will train technicians and operators in metrology has started. Results and knowledge from SIMET-GICP project will be taught in the full context and course sections in this education. This will be implemented over three days in March 2014.

7. Publications – see references

8. Conclusions and future research

The analysis made in 2007 of development needs in production engineering metrology ended with a "Sketch for SIMET," Fig. 3, containing the following basis:
"The overall objective with quality engineering and measurement technology work in the manufacturing of products, is to restrain the uncertainty to be as small as possible to assure that the manufactured product conforms in its function with the intended functional properties of the product."
The 2007 analysis was performed as a stepwise description of the different stages where uncertainty arises and with the connection to what could be considered as included in the zone in which the SIMET organization should be operating. By letting a PhD student focus on research and development of measurement and inspection planning in the first SIMET project, the stage 4 level in the analysis have been met. [10]
For the future there is a need to go on with further development as proposed below.

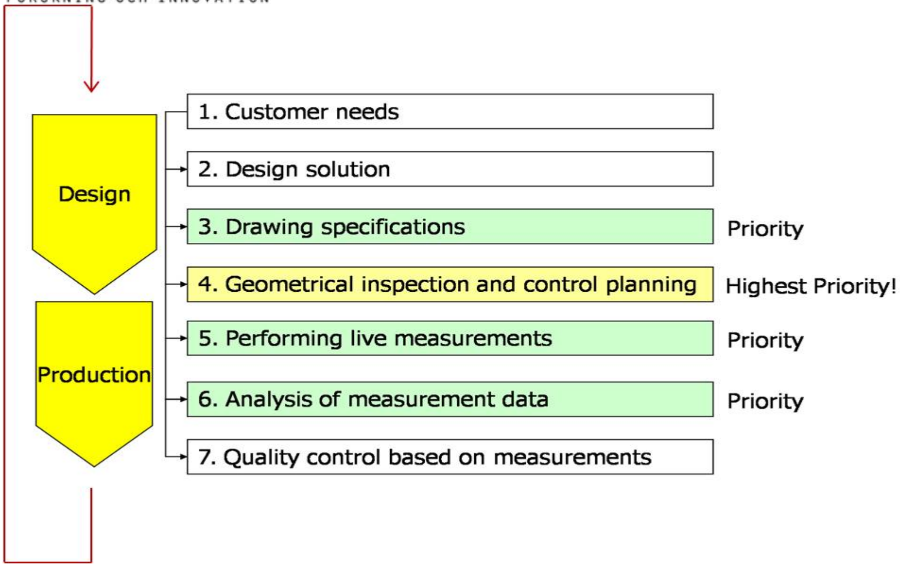

Fig. 3. Original classification of the research areas to be dealt with in SIMET

PROPOSED WORK

In the incremental compilation of Fig.3 "Sketch for SIMET" step 4, i.e."GICP", the next step to enter is #5, Performing live measurements. It is a natural choice as the next research work to be conducted, particularly with regard to how this step was defined in the sketch:

"Step 5 confirms that some uncertainty exists when the measurement and inspection planning is performed in practical measurements. Uncertainties include the risk that the planning may lack control of the influencing factors of the measurement as well as the normal measurement uncertainty that exists. "

Therefore we propose that this step, step 5, is taken as the next research target within SIMET and that adequate funding is raised to commence a research and development work in this area.

CONCRETE DESCRIPTION OF WORK AREA

The focus should be to relate practical measurements to the concepts for specification and verification requirements in the geometry area, which forms the basis of ISO's work on Geometrical Product Specifications, GPS.

This can be described by the following work plan:

1: Influence of different verification operators on the measurement result, linked to different manufacturing and measuring methods.

2: Development of guidelines for the selection of those operators, particularly where standardized specification operators are missing.

3: Development of simple tools for quantifying uncertainty, based on the principles for such type of analysis as stated in the JCGM 100:2008 standard: “Evaluation of

measurement data - Guide to the expression of uncertainty in measurement," and in the standards ISO 14253-1 and 14253-2.
Such tools are needed to obtain practically applicable analysis of measurements and measurement systems uncertainties, while considering all causes of uncertainty that arise in various forms of industrial production engineering metrology. In particular, a tool is needed that can be applied for this type of simpler analysis close to the manufacturing process.

Standardized work for model-driven development
In addition to the above project proposals within the SIMET research framework there is another project proposal, called MPQP - Model based Processing and Quality Planning. There, the aim is to develop a computer application for planning of manufacturing and GICP operations based on the STEP standard for exchange of data between different computer systems and applications. This can be seen as a competitor to the QIF standard that is being developed and produced by NIST in the United States. QIF is based on the XML standard and is built up of schema definitions and libraries rather than using direct semantic information as the STEP standard does. The latter is seen as a big advantage and strength.

9. Participating partners and contact persons

Project management group:
Industrial project manager (2010-2013), Mats Deleryd, kvalitetschef Volvo AB och Bo Eneholm, Renishaw, VD
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Ronnie Madsen, Saab Aeronautics, Geometrisäkring
Anders Viveland, Saab Aeronautics, kontrollberedning CMM:er
Erik Nordgren, LEAX AB, produktionschef
Richard Lindqvist, KTH Industriell Produktion, doktorand

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