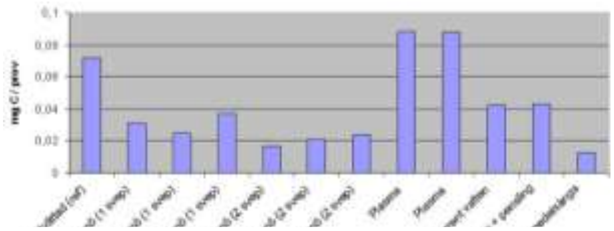
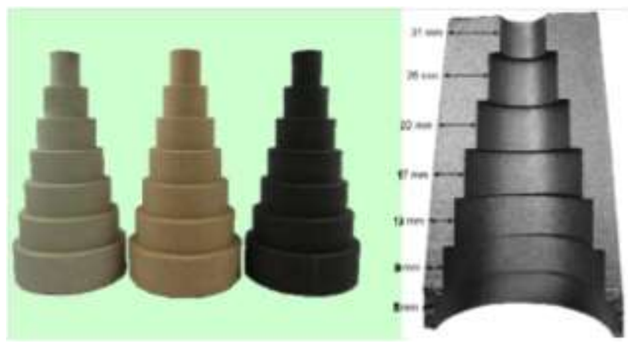
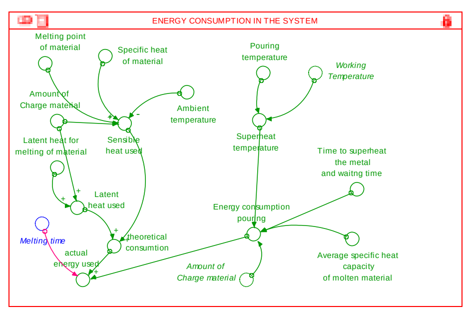
Public report

Sustainable Production Processes

Vinnova project 2009-00315







Project and research leaders

Eva Troell	Swerea IVF
Peter Nayström	Swerea Swecast
Lars Nyborg	Chalmers
Magnus Widfeldt	Swerea IVF (red)

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Content

1. Executive summary

The project ”Sustainable Production Processes” was executed from 2009 to 2012, within the FFI partnership between the Swedish government and the automotive industry, specifically within the collaboration program Sustainable Production Technology, Vinnova project no 2009-00315. Three specific work packages have been executed:

Work packages:	Work package leaders:
1. Sustainable heat treatment factories	Eva Troell, Swerea IVF
2. Sustainable casting production	Peter Nayström, Swerea SWECAST
3. Sustainable machine shops	Lars Nyborg, Chalmers

Project leader was initially Tero Stjernstoft, former Swerea IVF now Vinnova, and then Magnus Widfeldt, Swerea IVF.

Work package 1: Sustainable heat treatment factories

Objective: To minimise energy consumption and the use of chemicals and consumables during heat treatment, specifically during cleaning processes.

Results: *Key-index values for different heat treatment processes.* The energy needed per tonne heat treated materials is particularly related to the percentage used of the furnace cavity. The case hardening process needed three times more energy per tonne if the owen was filled to 10% compared to a fully loaded owen. Heat treatment neeeds clean material surfaces, and environmentally adapted cleaning is a key process.

Laboratory processes as well as procedures that can be suitable for application in connection to the heat treatment workshop have been evaluated regarding surface cleanliness after washing, prior the heat treatment process. Methods for evaluation and measurement of surface cleanliness have been examined. There is still need for research regarding how clean a surface needs to be depending on heat treatment process to be applied, e.g. nitriding or case carburizing. Knowledge transfer has taken place by the Swedish Heat Treatment Centre (Värmebehandlingscentrum) and Värmebehandlingsforum.

Work package 2: Sustainable casting production

Objective: To develop more cost-efficient casting production and make progress towards “the waste-free foundry” by reducing or eliminating the amount of foundry-generated waste, using waste as a resource in other processes, and reducing the need for virgin materials in the production of castings.

Results: *Increased internal reuse of sand* is possible due to improved cleaning methods. Bentonite-bound green sand containing coal dust has been recycled for production of cores. Two different recycling methods have been tested – mechanical and thermal. The results indicate that both methods provide recycled sand that is suitable for production of cores. This conclusion is based on physical tests and evaluation of the resulting castings.

The results of the *external recycling programme* include a handbook for recycling of moulding sand as landscaping fill. Especially useful has been Volvo Powertrain´s many years of experience in obtaining licences. The company has also acquired extensive knowledge of the properties of moulding sand in an environmental perspective. With the permission of the authorizing Swedish agency, surplus sand has also been used in pipe trenches with good results on the Scania company's manufacturing site. The resulting knowledge has been disseminated primarily via the Swedish Foundry Association.

Work package 3: Sustainable machine shops

Objective: To increase the prerequisites to implement sustainable cutting fluids in machine shops, including specific knowledge of the fluids functionality, evaluation of cleaning methods, health effects and waste management.

Results: *Environmentally adapted processing fluids/metal cutting fluids*. Exposure to cutting fluids aerosols beyond certain level, can lead to eye and skin irritation and respiratory effects. One possible reason can be bacteria and/or endotoxin from bacteria cell walls. Since cutting fluids can represent about 12% of the manufacturing costs, it is of crucial importance to maintain a proper control and handling as well as cleaning and recirculation in the factory. Knowledge about cleaning methods is important. Also, existing methods include use of biocides, may not be appropriate from health and environmental points of view. Cleaning by means of ozone treatment has been tested and evaluated by Chalmers using equipment built and developed by IO Trading. Cutting fluids for the experiments have been obtained from participating companies. The function and effect of the ozone treatment on bacteria control are demonstrated. In drilling experiments on cast aluminum, the lubricating effect of the cutting fluids have been maintained or even improved compared to the original (infected) cutting fluids. The ozone treated fluids also maintain their corrosion protection properties. Hence, the ozone treatment does not affect the machining.

A theoretical study has also been accomplished at KTH, regarding *decision support for residual products handling*, including setting of a framework for ”Resource Conservative Manufacturing”. This framework includes strategies for OEM and models for minimizing of residual products. Applied studies has then been performed to develop decision support for reduced energy consumption in casting of cylinder heads and machining of crank shafts using the simulation tools System Dynamics and Stella.

2. Background

The demands on production of new powertrain components will increase, to reduce or eliminate negative environmental effects during manufacturing. The objectives are to reduce or eliminate waste, minimize the need of virgin materials, minimize the use of energy and minimize or eliminate health impact. This project, "Sustainable Production Processes", was executed from 2009-06 to 2012-03, and was funded by the FFI partnership between the Swedish government and automotive industry for joint funding of research, innovation and development, concentrating on Climate & Environment and Safety. The FFI partnership is handled by Vinnova, Swedish Governmental Agency for Innovation Systems. This specific project was included in the FFI program Sustainable Production Technology.

3. Objective

The long term roadmap on component manufacturing, created within the FFI partnership, follows the overall vision to reduce or eliminate the environmental impact from vehicle component manufacturing. The aim of this project, sustainable production processes, has been to deliver clear results, in the direction of the vision, from three specific areas: Heat treatment, casting production and cleaning of process liquids used in machining operations.

4. Project realization

The projects three focus areas were: "Sustainable heat treatment factories", "Sustainable casting production" and "Sustainable machine shops – Fluids and Waste management".

4.1 Sustainable heat treatment factories

Heat treatment is a process performed at the end of the production chain. It is often time-consuming, and needs to become more efficient, while the consumption of chemicals and energy consumption needs to be minimized both from an environmental and cost stand-point. Focus has been:

- To develop key-indicators for various heat treatment processes. These shows energy consumption per tonne of heat-treated goods. The load in the furnace has a major impact on the key indicator. When case hardening, the energy consumption was three times higher when the load ratio was 10% compared with a fully loaded furnace
- To investigate methods for evaluation of cleanliness after washing in laboratories and in connection with the production. Several laboratory-adapted techniques, e.g. FTIR, are suitable to evaluate the type of contamination on the surface. To evaluate the amount of contaminations IMC and LIF can be suitable. These methods could also be adjusted to be used in connection with the production. Further research and analysis is required to enable the calibration of cleanliness before heat treatment, i.e. how clean a surface needs to be before the heat treatment
- To study the possibilities of eco-adapted cleaning methods as plasma cleaning, carbon dioxide snow and ultrapure water.

Reduced energy consumption: Key performance inducators

The energy use for some of the most common heat treatment processes have been measured for different furnaces and different charge loads. For this application, key indicators MWh / tonne load and MWh/mm case depth was chosen as most representative. The measurements made, included heat treatment processes; tempering, case hardening and nitrocarburizing. Preheating /oxidation were excluded, therefore measurements began at about 400 °C. Various furnaces such as batch and throughput furnaces were included. Measurements were made for different charge weights (loads) where the furnace fill rate ranged from 10-100%. Fixture materials, i.e. baskets, were included in the weight, figure 1.

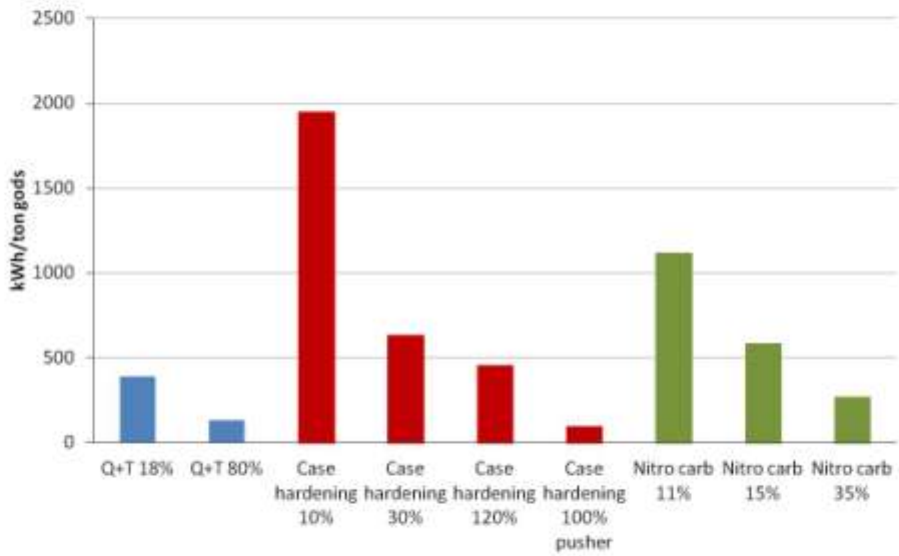

Figure 1. Energy consumption in kWh/tonne at various heat treatment processes, as well as at various filling rates of the furnaces.

Reduced chemical consumption - methods for evaluation of cleanliness

In the project washing before heat treatment has been studied with the long term goal of minimizing the use of chemicals in the wash. Surface condition, including cleanliness, has a great influence on the heat treatment result. Knowledge of how to evaluate the surfaces cleanliness and how to wash the surface in the best way is required in order to optimize the washing process, both regarding the choice of chemicals and washing method as well as frequency of changing the bath. Environmentally friendly cleaning methods can reduce the use of chemicals and energy.

Methods to evaluate the cleanliness of surfaces

The procedure has been:

1. Sample Preparation. Steel 42CrMo4, ø25 x 10 mm, milled with commercial cutting fluid (Variocut C462, Hysol 3505)
2. Cleaning with eco-adapted methods; plasma, CO_2 snow and ultraclean water.
3. Analysis: FTIR, IMC, LIF, in order to classify the degree and type of contamination
4. Nitrocarburizing and optical analysis of compound layer thickness.

The objective was to evaluate the possibility of using more environmentally friendly cleaning methods. Limitations, opportunities and needs for further development are investigated.

Results of cleaning with environmentally adapted methods

Traditional cleaning is done with detergent at about 60°C. Several baths are used in a sequence. The final wash performance is highly dependent of the cleanliness in the last rinse step. The environmentally friendly methods that have been evaluated in the project are low-temperature plasma, ultraclean water as "Qlean process" and CO_2 snow. There are also more traditional methods that could be relevant such as closed solvent recovery system. In the evaluation flat steel samples were used. Below is a summary of the studied methods:

- **Cleaning with plasma**. This method is suitable for removing small amounts of impurities, such as fingerprints, but in these experiments coolant residues was the contamination and these burned onto the surface
- **Cleaning with CO_2 snow.** Two sweeps CO_2 snow resulted in the cleanest surfaces
- **Cleaning with ultraclean water.** In this study the result was impacted by a non-optimized drying process for the application, which resulted in some corroding of the cleaned surfaces. A comparison with traditional cleaning has shown that greenhouse gas emissions are about 40% lower with the use of ultraclean water.

Interesting for further studies are cleaning with CO_2 snow and ultraclean water. Both methods require adaptation to the component geometry and actions for industrialization. Before the implementation of new methods cleanliness requirements before various heat treatment processes is needed.

4.2 Sustainable casting production

The objective has been to develop new technology and methods for more efficient use of resources while minimizing climatic and other environmental impacts in the production of castings. The focus has specifically been on internal reuse and external recycling of moulding sand.

Internal reuse of moulding sand

The overall objective has been to reduce the amount of waste from greensand foundries by reusing surplus sand in the production of cores. Currently, green sand is regarded as insufficiently pure for core production. Detailed reports:

1. Gotthardsson, U. *Från råsand till kärnsand*. Swerea SWECAST 2012-001
2. Nayström, P. Eight status reports on the project (in Swedish). Swerea SWECAST

Four cleaning methods have been evaluated, using moulding sand from the Arvika, Xylem and Volvo foundries. The material from Arvika and Xylem was ”traditional” green sand. The sand from Volvo was a mixture of approximately 25% green sand and 75% core sand.

Methods tested for cleaning of moulding sand

1. Gemco 30. Mechanical cleaning in a batcher with Gemco Sand Cleaner.
   Process time: 30 minutes. Sand from Arvika, Volvo and Xylem foundries.
2. Gemco 60: Mechanical cleaning in a batcher with Gemco Sand Cleaner.
   Process time: 60 minutes. Sand from Arvika, Volvo and Xylem foundries.
3. Richards M: Continuous flow mechanical cleaning.
   400 kg for ca 10–20 minutes. Sand from Volvo foundry.
4. Richards T: Thermal and mechanical cleaning. Sand from Volvo foundry.

The following properties have been evaluated after test cleaning of moulding sand:

Grain size distribution

Change in mean grain size with the alternative methods (larger/unchanged/smaller).

Mineral composition

Silica, $Si0_2$ and feldspar (two types: albite (NaAlSbOs) and microline (KAlSbOs)). The mineral composition of the different recycled sands varied greatly.

Carbon content/loss of ignition (LOI)

The thermally recycled sand had the least ignition loss or carbon content by a clear margin, even lower than fresh sand's. However, the cleanest sand is not necessarily the best suited for production of cores.

Permeability

The sands recycled with Gemco's equipment had lower permeability than fresh sand. The sands recycled with the Richards mechanical and thermal methods had greater permeability than the Gemco sands — roughly the same as in fresh sand.

Core properties

The Gemco sands seemed to be easier to work with in the production of test bars and cores; not as much parting agent was required. The dark colour of the Gemco sands made it more difficult to check for joint flashes.

Bending strength

With the Gemco method, bending strength seems to be the same as that of the core sand that the three foundries normally use. The bending strength seems to increase with increased process time, but longer times also increase the variation of the results.

Castability with cores of recycled sand

An evaluation of the casting of stepcone cores found no significant differences between the various cores. No mixture was found to be significantly better or worse than any other. Figure 2.

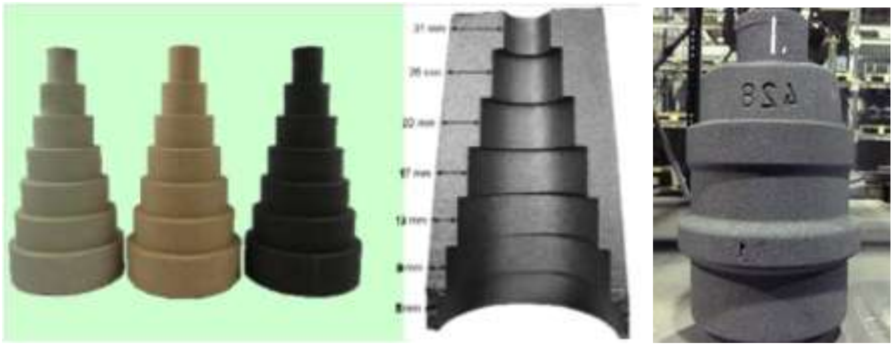

Figure 2. Left: stepcone cores. Centre: Casting to be tested. Right: Production core made of recycled sand and coldbox binder. Photos from project status report #8 by Peter Nayström.

Core properties

When Arvika made test castings with one of its cores in a PU coldbox, the recycled sand resulted in casting surfaces almost as good as those made with fresh sand.

Dust properties

Concentrations of both bentonite and carbon in the dust decreased by nearly half when the process time was increased from 30 to 60 minutes. Accordingly, the earliest dust from each batch is the best to use for recycling.

Results of recycling

A process time of 30 minutes yielded 70–75% reusable sand and 25-30% dust. A period of 60 minutes yielded ca 60% reusable sand and 40% dust. The Componenta foundry in Weert, Netherlands, has found that most of the separated dust can be mixed directly with green sand; fresh sand at a proportion higher than 10% increases problems with finnings.

External recycling of foundry sand

Regarding the use of recycled foundry sand as raw material in other applications, several new possibilities have been evaluated, and knowledge has been assembled, supplemented and reported by external sources:

- Moulding sand as fill material
- Handbook on the reuse of moulding sand as fill material
- External recycling initiatives in collaboration with project partners.

Moulding sand as fill material

A report by Annika Åberg[1] reviews the knowledge gained about moulding sand´s technical and environmental properties, when reused as fill material. The report includes an evalua-

[1] Åberg, Annika. ”Formsand som utfyllnadsmaterial — erfarenheter av formsandens tekniska och miljömässiga *egenskaper* vid återanvändning vid utfyllnadsområden.” Rapport no. 2012-002. Hifab AB and Swerea SWECAST.

tion of bentonite-bound moulding sand´s technical and chemical properties. The evaluation is based on data from Volvo Powertrain in Skövde, Sweden. The moulding sand's chemical properties are so favourable that it has the potential to fulfil the Swedish Environmental Protection Agency's criteria for minimal risk with recycling for landscaping purposes. Currently, the biggest obstacle to fulfilment of the criteria is the leaching of salts.

Handbook for the use of moulding sand as fill material

Annika Åberg has produced a handbook[2] that provides foundries with guidance in reusing moulding sand as fill material instead of simply dumping it. Knowledge acquired from Volvo Powertrain is primarily concerned with the reuse of bentonite-bound moulding sand, and is not necessarily applicable in all circumstances. Bentonite concentrations vary between foundries, and local authorities may impose varying requirements for the permeability of the filling. The handbook's guidance refers to two concentrations of bentonite — 6% and 3%. All reuse of moulding sand as fill material in Sweden must be reported in accordance with Ordinance SFS 1998:899 concerning Environmentally Hazardous Activities and Health Protection. Reuse of moulding sand must always be reported in advance to the relevant municipality. A sample notification form is included as an annex to the handbook.

External recycling initiatives

Figure 3. External recycling of foundry sand. Left: Use of foundry sand and cupola furnace slag as fill material at Volvo in Skövde. Centre: Foundry sand in pipe trenches at Scania in Södertälje. Right: Sand from Arvika foundry used as landfill material.

Some good examples of external recycling are shown in Figure 3. A compilation of such examples is available on the CD, "Gjuterisand — En del i kretsloppssamhället" (Swedish only; order via swecast@swerea.se). In connection with the project, 1000 metric tons of moulding sand were delivered to the Boliden for tests of its use in melt processes. The ITT Flygt foundry has developed a database that registers all waste and surplus materials. A plan to use foundry sand in a furnace with a fluidized sandbed was discontinued, when it was determined that the sand to be used could cause blasting damage to the furnace.

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2 Åberg, Annika. "Handbok: Prövning och bedömning av formsandens tekniska och miljömässiga egenskaper vid återanvändning som fyllningsmaterial" Rapport no. 2012-003. Hifab AB and Swerea SWECAST.

4.3 Sustainable machine shops – Fluids and Waste Management

The overall objective has been, to establish a basis for the implementation of environmentally adapted cutting fluids in machine shops, by means of increased knowledge about the functionality of cutting fluids, evaluation of alternative methods for bacteria control, health aspects (work environment) and knowledge development regarding residual product management. See report: "Alternative Cutting Fluid Cleaning. Major work performed within the WP "Sustainable Machine Shops" in the FFI project "Sustainable Factories". E. Tam, L. Nyborg, V. Nayyar, et al. Chalmers, april 2012.

Environmentally adapted processing fluids/metal working fluids

Cutting fluids are used daily in machine shops of manufacturing companies. Exposure to cutting fluids above certain level may cause eye and skin irritation as well as respiratory effects. One possible factor is the bacteria and endotoxins from bacteria walls. The bacteria is today controlled by biocides addition. Regulations like REACH will impose more and more restrictions to the use of biocides, and alternative methods are therefore needed. Since the cutting fluids may represent as much as 12% of the manufacturing costs, it is important to maintain a proper control and handling as well as cleaning and recirculation.

Ozone treatment – principles and equipment

An alternative method for cleaning of cutting fluids with respect to microorganisms has been tested and evaluated. The practical work has been done using a prototype machine developed by IO Trading, the machine has been facilitated for the experiments performed at Chalmers (figure 4). The processing liquid to be treated is kept in its tank beside the machine and it is then circulated, treated and returned to the tank. To make sure that the ozone is not decomposed, the temperature must be below 25°C. Ozone (O_3) is a strong oxidant with very strong bacteria killing effect, the ozone is supposed to act 3000 times faster than chlorine. Ozone is a poison and can cause eye irritation, headache and respiratory effects. The EU directives 2008/50/EC and 2002/03/EC provide clear and consistent information about exposure limits for humans over shorter and longer time periods. The ozone can decompose and form oxygen.

Figure 4. Equipment for ozone treatment (IO Trading & Teknik Corporation)

Cutting Fluids

Cutting fluids from different manufacturing processes have been delivered to Chalmers. The fluids are designated as A, B, C, D and E. They are basically standard fluids where microbial growth has been suspected. To confirm this and select liquids for ozon treatment tests, all fluids were checked for their content of bacteria, endotoxin and mould, see table 1. The microorganism measurements were done at Sahlgrenska University Hospital.

Table 1. *Content of bacteria, endotoxins and mould in cutting fluids delivered to Chalmers before ozone treatment: cfu/ml=colony forming units/ml (amount of bacteria or mould/ml), EU/ml=endotoxin units/ml.*

Sample	Bacteria (cfu/ml)	Endotoxins (EU/ml)	Mould (cfu/ml)
A1	9.9 x 10^3	1701	< 10
A2	4.3 x 10^4	1097	< 10
B1	< 1.0 x 10^3	< 50	< 10
B2	< 1.0 x 10^3	< 50	< 10
C1	*5.6 x 10^6*	*3718*	*30*
C2	*1.0 x 10^7*	*2766*	*30*
D1	< 200	742	< 20
D2	< 200	844	< 20
E	1.2 x 10^5	3626	< 10

Bacteria count below 10^3 cfu/ml indicates the control by biocides (or other effect) has been good. Counts above 10^6 cfu/ml means unsatisfactory control of bacteria growth. Among the liquids in table 1, liquids C and E were therefore selected for ozone treatment, which was done in april 2011 and january 2012, in co-operation with IO Trading & Teknik AB, using the equipment shown in figure 4.

Results from ozon treatment experiments

The working principle and effectiveness of ozone treatment as means for bacteria control has been demonstrated. The ozone treatment proved to be very efficient. After 90 min the bacteria count was below 200 cfu/ml. This is actually below the measuring limit and a count of 1000 cfu/ml is taken as measure of effective cleaning. There is no effect of the ozone treatment on endotoxin levels. For fluid C increased endotoxin level was found after 90 min ozone treatment. One possible reason could be that endotoxines are released when the initial bacteria is killed. This mechanisms is however not clear and conclusions cannot be made regarding mechanisms. For both cutting fluids treated, slightly increased mould count is indicated after ozone treatment. Still, also here the change is too small for definite conclusions.

Machining tests

Machining tests have been performed with the selected fluids before and after ozone treatment. The tests have been performed by drilling in cast aluminium. The tests have been designed according to principles developed in a previous project. Drilling in aluminium requires good lubrication and if the lubricity is lost this will show directly in the tests. The measurement of forces (torque and thrust), see figure 5, as well as surface integrity, shows that lubricity of the cutting fluids most probably is restored by the ozone treatment. Forces are smaller when drilling with treated cutting fluid then when drilling with untreated. Hence, the functionality of the cutting fluid is not affected negatively by the ozone treatment.

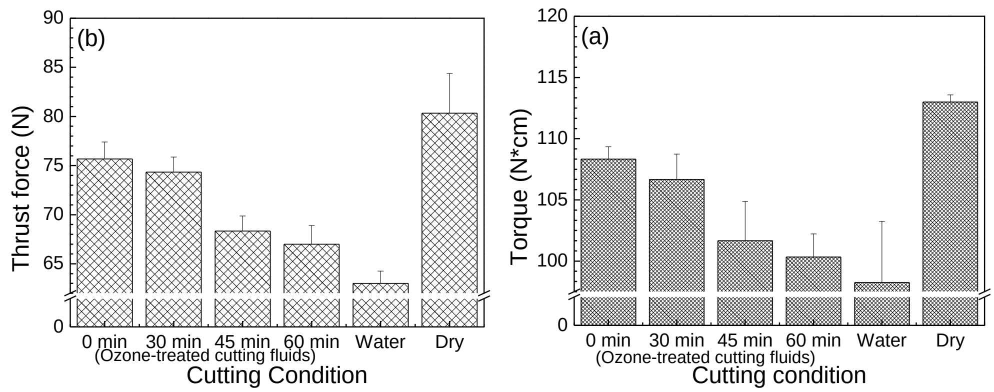

Figure 5. *Forces (thrust and torque) when drilling in cast aluminium with differently ozone treated cutting fluids. Data for drilling with water and dry are also showed for comparison.*

Corrosion test

In order to examine whether ozone treatment affects the corrosion protective properties of the cutting fluid, electrochemical polarization measurements have been done. The polarization measurements have been using pure iron as test material and the cutting fluids as electrolytes. The polarisation scan has been from -0.70 to +1.20 V. The results show that the polarisation curves are quite similar for the different cutting fluids irrespective if they are ozone treated or not. The passive current density is $< 10^{-4}$ A/cm^2. This shows that their corrosion protection properties are basically equal. Furthermore, standard test by exposing chips in the liquids were performed. Also this test indicated that the corrosion protective properties were maintained.

Summary

Ozone treatment has been applied as means of microorganism control for contaminated metal working fluids. The results show that treatment for 90 min can reduce the bacteria counts substantially to levels below detection limits. The level of endotoxins is not significantly during the treatment. The ozone treated cutting fluids maintains its functionality in machining and has also preserved corrosion protection properties. Adding cost estimates to the evaluation, it can be expected that the relatively low running costs for the method makes it feasible to implement the method in industrial application.

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Residual products handling

A theoretical study has been performed regarding decision support for residuals management by KTH. A framework has been established for future research. The framework ”Resource Conservative Manufacturing” includes strategies for OEM and models for minimizing rest products. Further information can be found in: Asif, F.M.A. (2012) Resource Conservative Manufacturing, A new generation of manufacturing, Lic Thesis, KTH Production Engineering, Sweden. http://kth.diva-portal.org/smash/record.jsf?pid=diva2:441383

Case studies – energy efficiency in manufacturing

Two case studies have been performed using the simulation by means of System Dynamics (SD) and Stella. The purpose has been to evaluate the energy efficiency and contribute to decision making support when considering ways of reduced energy consumption. Focus for one of the studies was the casting of cylinder heads, and the other study addressed the manufacture of crank shafts. The SD-model for energy usage in casting is illustrated in figure 6.

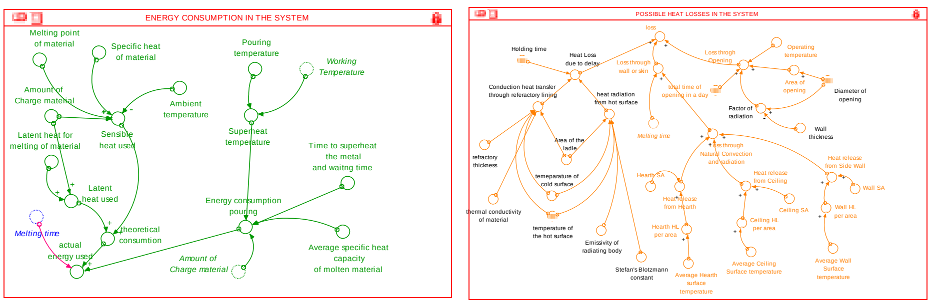

Figure 6. *Model for energy mapping by means of system dynamics approach for the casting process at SCANIA.*

The most important possibilities identified to realize decreased energy consumption are:

- ”Timing between preparation of finished melt and start of casting process”. The energy saving is about 1321200 kJ if the waiting time can be shortened from 40 to 30 min
- ”Temperature of residual material from casting moulds”. If the mould can be separated from the cylinder head at higher temperature than today, there is great gain in energy savings. Compared to current conditions, each 10° C higher temperature means about 460800 kJ of energy savings.

5. Results and deliverables

The vision of eliminating environmental impacts from the production of components for the automotive industry also includes the objective of increasing the competitiveness of vehicle manufacturers. That is entirely consistent with FFI’s overarching goal.

WP1 Sustainable Heat Treatment Factories

- Reduced energy consumption during heat treatment in order to reduce costs and emissions
- Reduced use of chemicals by facilitating measure and evaluate cleanliness of components prior heat treatment.

WP2 Sustainable Casting Production,

The project results indicate that it is possible to:

- Minimize the amount of foundry waste and the extraction of finite natural resources for foundry processes
- Identify possible ways to reuse surplus materials from casting processes.

WP3 Sustainable Machine Shops

- Established improved possibilities for implementation of environmentally adapted cutting fluids in machine shops
- Assessment of alternative treatment methods for microorganism control with potentially better environmental, cost and health impact footprint
- Development of platform for ”Resource Conservative Manufacturing” including decision making support for OEM and theoretical models.

6. Dissemination and publications

6.1 Knowledge and results dissemination

2009-11-04	Presentations at ”Processvätskecentrum” annual meeting and autumn seminar. General knowledge transformation through ”Processvätskecentrum”
2009-11	Pressrelease via Swerea, se http://www.swerea.se/Documents/Pressmeddelanden/2009-11-17%20Pressinformation_Swerea_IVF.pdf and http://www.webfinanser.com/nyheter/176737/miljovanliga-och-energieffektiva-fabriker/
2010-04-22	Project presentation ”Mera FFI – dag” at Scania.
2010-06-01/02	Project and WP presentations at the cluster conference in Katrineholm.
2010-06-08	Kickoff meeting at Swerea IVF
2010-10-19	Project presentation at Vinnovas FFI-day, Technical Fair/Tekniska Mässan
2010-11	Article in Teknikföretagen Direkt #5 nov 2010
2011-01-27	Presentation at VBCs member meeting
2012-02-02	Presentation at VBCs member meeting
2012-03-08	Presentation of the project and heat treatment parts at the SHTEs (Swedish Heat Treatment Suppliers) member meeting
2009 – 2012	Continuous presentations, 8 newsletters on sustainable casting production, system dynamics seminars etc.

6.2 Publications

1. Cleaning prior heat treatment - evaluation of analytical techniques and study of environmental adapted cleaning methods
2. Energieffektivisering av värmebehandlingsprocesser - nyckeltal
3. ”Från råsand till kärnsand”. Gotthardsson, U. Swerea SWECAST 2012-001
4. ”Formsand som utfyllnadsmaterial – erfarenheter av formsandens tekniska och miljömässiga egenskaper vid återanvändning vid utfyllnadsområden”. Åberg, Annika, Hifab AB. Swerea SWECAST rapport nr 2012-002
5. ”Handbok – Prövning och bedömning av formsandens tekniska och miljömässiga egenskaper vid återanvändning som fyllningsmaterial”. Åberg, Annika, Hifab AB: Swerea SWECAST rapport nr 2012-003
6. CD ”Gjuterisand – En del i kretsloppssamhället”, kan beställas från swecast@swerea.se
7. “Alternative Cutting Fluid Cleaning. Major work performed within the WP “Sustainable Machine Shops” in the FFI-project “Sustainable Factories”. Nyborg, L et al. Chalmers, april 2012
8. Asif, F.M.A. (2012) Resource Conservative Manufacturing, A new generation of manufacturing, Licentiate Thesis, KTH Production Engineering, Sverige. Utöver denna är en journalpublikation under granskning, en är under framtagning

6.3 Collaboration to other projects

FFI-projects

- DFBB, digital factory building blocks
- Green production systems
- FFI pre study Green and Lean Production Navigator.

Networks

- Heat treatment forum, The Swedish Foundry Association, Processvätskecentrum (MCR, DMMS)
- Network for more efficient use of energy, ENIG
- AFA-project at Sahlgrenska related to WP3

FFI Component Cluster Roadmap

The long term roadmap concerning component manufacturing, created by the FFI Component Cluster, is a very important guideline for present and coming research initiatives.

Lean och Process

On the one hand, there is an increasing number of components in powertrains, and on the other hand, there are demands on manufacturing to reduce batch sizes and buffers. This results in new requirements on flexibility, to reduce change over times and to develop efficient in line manufacturing processes.

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7. Conclusions and future research

The FFI long term overall roadmap is divided into specific clusters. This project is part of the Component Cluster Roadmap, manufacturing processes, with focus on "New materials and environmentally friendly manufacturing technology". A new step has been taken by the Component Cluster, to form an R&D project called "EnviroMan", Environmentally adapted metal manufacturing processes: chemicals, energy and waste material recycling. The EnviroMan project plans to cover a pilot methodology on energy mapping within manufacturing processes.

8. Participating parties

Valuable contributions are delivered by the project partners:

1. Kungliga Tekniska Högskolan, KTH. Institutionen för industriell produktion	2. Chalmers tekniska högskola AB. Institutionen för material- och tillverkningsteknik
3. SWEREA IVF	4. Swerea SWECAST
5. Swerea KIMAB	6. HIFAB AB
7. Sahlgrenska universitetssjukhuset. Arbets- och miljömedicin	8. Volvo Cars
9. Scania CV AB	10. AB Volvo
11. SKF Sverige AB	12. SKF Mekan
13. AGA Gas AB	14. Parker Hannifin
15. Sarlin Furnaces	16. Atlas Copco Secoroc
17. ITT Water and Wastewater	18. Heidelberg Cement Miljö AB
19. Karlskoga Kraftvärmeverk AB (*discontinued their participation for technical reasons*)	
Members of the FKG, the Scandinavian automotive supplier association	
20. Getrag All Wheel Drive AB	21. Nya Arvika Gjuteri AB
22. Bodycote Värmebehandling	23. Finnveden Powertrain AB