

## **Energy and Water Efficiency in the Automotive Sector: A Case Study on the Potential to Improve the Economical and Ecological Performance of an Automotive Supplier**

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Starting in December 2008, a comprehensive potential study was carried out to improve the existing performance of an automotive supplier with the focus on the technological system optimisation of the production line “die-casting”. By analysing the company in terms of production output, production processes, system boundaries, resource efficiency, etc., optimisation measures were worked out, which allow an effective usage of waste heat streams and the reuse of water and chemicals in wet processing systems.

### **1. Introduction**

The automotive industry is one of Austria’s most important industrial sectors with nearly 700 companies and 175,000 people employed in this branch of industry. This sector comprises the complete value chain, in particular in the areas of engineering services, metal working, metal processing, electronic systems and die-casting. The more often applied die-casting process within the automotive sector is high-pressure die-casting (HPDC), due to the possibility of reaching high output rates and to produce complex light metal components with low wall thicknesses (Tharumarajah, 2008). In contrary to other production steps of automotive suppliers, the manufacturing of die cast components requires the input of large amounts of thermal energy and water. Especially for larger companies, there are possibilities to integrate the waste heat streams from the die-casting line into the hot water supply system in a worthwhile way and thus increasing the energy efficiency of the whole process to a more economical and profitable performance. Water is primarily used for cooling purposes, e.g. to cool the casting forms and for die-casting cooling baths for heat treatment. This is primarily done via internal closed cooling cycles, which allows a substantial reduction in the fresh water demand and wastewater formation. Water is also used for cleaning purposes and as carrier medium for water soluble release agents. Generally, these release agents are highly responsible for the casting quality, the surface finish, the ease of cavity fill and the ease of casting ejection. The used release agents can also speed up the casting rate, reduce maintenance requirements and reduce the accumulation of material on the die face (EIPPCB, 2005). The direct reuse of these excess release agents has to be seen critical, as thermal stress during the first usage can change the chemical structure of the included additives (e.g. additives to inhibit corrosion, to resist bacterial degradation,

etc.) and therefore quality problems may arise when used again. Leaks in the hydraulic systems of die-casting devices can also lead to a consequent transport of the leaked liquid into the water system and therefore to the presence of glycols in the excess release agent (partial wastewater stream of the die-casting line). Therefore, the direct reuse of these excess release agents is not applied in most of the cases and the wastewater stream is treated using end of pipe measures. However, by modifications of the operation processes and the integration of adequate treatment systems, the overall performance of the internal water management can be improved and the cleaned wastewater may be reused as solvent for the release agent.

Water is used for cleaning purposes in the processing industry as many manufacturing processes require cleaning steps within the process chain for degreasing and cleaning metal surfaces to gain an optimal product quality in the following process steps. These cleaning steps are not the core business of manufacturing companies and due to their classification as marginal process steps, the specific knowledge on cleaning processes can often be seen as limited within individual companies. Thereby, in many cases a high potential to enhance the operating performance and to reduce the specific costs on these processes is given. Furthermore, these cleaning processes become more and more important as independent process steps within the value added chain, as increasing quality standards require a defined cleanliness of component surfaces.

## **2. Methodology**

In most of the cases the resource “water” is counted among those production factors, which do not directly enter the product, but are responsible for the proper operation of processes. Therefore, the production factor “water” is responsible for the transport of materials and energy, water is used for cleaning purposes and as solvent, but also to remove pollutants from water based processes. On the other hand most industrial processes need thermal energy (heat), supplied by heating boilers or directly provided via primary energy input (e.g. natural gas) in melting, drying or hardening processes. Thus, the industrial water and energy system consists of several sub-systems which are more or less connected or influenced by each other in a more or less intensive way. This strong conjunction of water and heat management at industrial sites requires a systematic approach to design the best possible concept for the simultaneous water and energy reduction. System boundaries and therefore communication boundaries between different divisions within one company have to be reflected to identify the main variables influencing the energy and water demand and to define a systematic approach for the implementation of optimisation measures in the context of long-ranging investment decisions, orientating on the future development of the company site. Therefore, at the beginning of the potential study a detailed system analysis was carried out to define all relevant process and resource streams within the company and to collect and analyse the specific process and production data for this fields. Mainly against the background of an efficient heat recovery, the system boundaries of the production line die-casting were expanded to the whole company and, in doing so, to the production lines hardening and mechanical processing. Thus, the systematic analysis of the expanded system die-casting also required the investigation of relevant processes

and production fields, which are associated with the system die-casting. Processes which were investigated in detail are: System die-casting with the focus on melting/holding furnaces and external HPDC cooling (water soluble release agent); System mechanical processing with the focus on component cleaning processes; System hardening with the focus on component cleaning processes and hardening furnace; System wastewater treatment and internal water management; System central heating with the focus on hot water supply.

### **2.1 System analysis and data acquisition**

Thermal energy is required as natural gas for two installed heating boilers (5 MW and 3 MW) and for aluminium melting and its maintenance in the molten state. The specific gas demand of the different production lines formed the basis for the further investigations on possible optimisation measures in the case of thermal heat recovery. The 5 MW heating boiler is used as peak load boiler as the company site had been originally planned much bigger and an additional production line had been provided. With the 3 MW and 5 MW heating boiler a hot water recirculation pipe with a flow temperature of 80-90 °C is supplied. Directly connected to the hot water recirculation pipe, seven cleaning processes are the main consumers of the generated hot water with a total process heat demand of 5,800 MWh/y (basis 2009). Within the production line die-casting, there is no need for hot water. The hot exhaust gases are emitted via shared collector stack. To evaluate the specific heat demand of the cleaning processes, extensive measurements have been carried out, whereas two facilities were identified as main process heat consumers. Within the system die-casting five gas fired furnaces (4 facilities to maintain the molten aluminium in the molten state and 1 melting furnace) are the only gas consumers with a total heat demand of around 6,500 MWh/y (basis 2009). Aluminium is completely delivered to the company in the molten state in specific thermal containers and kept molten in the company before used. The melting furnace is used to recover the aluminium from rejected pieces and aluminium residues. The hot exhaust gases of the five gas-fired furnaces are emitted via shared collector stack. Within the system hardening four hardening furnaces with integrated cleaning processes are the main consumers of thermal energy. The cleaning processes are supplied with hot process water via the mentioned recirculation pipe, whereas the hardening furnaces are directly supplied with gas for the hardening process. The hot exhaust gases of the hardening furnaces are emitted via shared collector stack.

The wastewater from the production lines mechanical processing, hardening and die-casting is treated in a vacuum evaporator with a maximum capacity of 23 m<sup>3</sup>/d. The vacuum evaporator is operated under contracting arrangements by an external partner. The energy supply is carried out by 1/3 with waste heat of the company's air compressor units and by 2/3 with electrical energy. Due to capacity problems of the vacuum evaporator, nearly 30 % of the yearly wastewater flow has to be discharged externally. The distillate is discharged to the public sewage system. To verify the yearly wastewater effluent from the die-casting line, measurements were carried out and projected on the basis of the product output and on the specific fresh water demand per shot (produced die cast component). Thus, it could be shown that nearly 65 % of the yearly wastewater flow has to be attributed to the die-casting line (7 HPCD facilities),

mainly polluted with excess release agents, hydraulic oils and grease. Cleaning processes (15 facilities) within the production line mechanical processing and hardening are responsible for about 20 % of the yearly wastewater flow, the leftover can be allocated to old cooling lubricant emulsions used in cutting processes (e.g. mechanical processing / chipping) and to general cleaning works.

### 3. Results and Discussion

To determine potential options to increase the overall performance of the company by waste heat recovery and process water reuse, reduction options were analysed in detail and factors, which limit the successful implementation were defined and evaluated. The reduction options clarified below have been worked out in detail taking into account the limiting factors identified within the system analysis. One reduction option, regarding the heat recovery within the die-casting line, provides the integration of a heat exchanger to raise the return temperature of the recirculation pipe of the company's hot water supply system. As no potential heat sink within the system "die-casting" could be identified, this solution enables the efficient recovery of 184 MWh/y waste heat within the expanded system "die-casting".

*Table 1: Usable waste heat within the expanded system die-casting (\* taking into account limiting factors identified in the project)*

System	Available waste heat	Usable waste heat	Natural gas reduction
Die-casting	576 MWh/y	184 MWh/y*	19,913 m <sup>3</sup> /y*
Hardening	517 MWh/y	0 MWh/y*	0 m <sup>3</sup> /y*
Central heating	181 MWh/y	181 MWh/y*	19,598 m <sup>3</sup> /y*
Total	1,274 MWh/y	365 MWh/y*	39,511 m <sup>3</sup> /y*

To recover the usable waste heat within the system "die-casting", the exhaust gas has to be cooled down from 140 °C to 110 °C and used to raise the return temperature of the recirculation pipe. By cooling down the exhaust gas to 110 °C, an appropriate distance to the dew-point temperature will be given and therefore the condensation of water and corrosion problems due to the formation of acids can be avoided. As the performance of the heat exchanger can be influenced negatively by impurities in the exhaust gas, the planning phase of such heat recovery measures should also include the evaluation of the used additives in the melting process. This includes in particular the consideration of the possible usage of additives to remove impurities from the molten aluminium or to remove the slag when cleaning the melting furnace. However, negative side effects to the durability of the heat exchanger could be ruled out in the investigated case, as additives are not used for the melting process within the company. Nevertheless, to avoid negative side effects in the case of cleaning and maintenance works, an option to by-pass the heat exchanger was included in the concept. To recover the useable waste heat of the central heating system, the reduction option provides the integration of a heat exchanger (economiser) into the collector stack to raise the return temperature of the recirculation pipe. The possible reduction of natural gas is calculated on the basis of

cooling down the exhaust gas to 100 °C taking into consideration the reduced gas demand (reduced usable waste heat) when realising the waste heat integration measure within the system die-casting. In both cases, a certain amount of the available waste heat of the systems die-casting and central heating (Table 1) can be used indirectly to supply the component cleaning processes within the system mechanical processing in an economical way. To improve the economical and ecological performance of the component cleaning processes additional options were investigated, especially regarding possible measures to extend the lifetime of the washing baths. Besides commonly used oil separators the practical application of membrane filtration technologies for the effective removal of pollutants to enhance the lifetime of the washings baths was evaluated. Therefore, in the course of laboratory and pilot experiments with ultrafiltration membranes the effective removal of oil and grease with the simultaneous recovery of surfactants could be demonstrated. However, for an economical integration in existing cleaning processes the technology of ultrafiltration as well as oil separators or any other kind of treatment technology always has to be adapted to the specific process and production conditions. Therefore, in the present case all 15 component cleaning machines were evaluated taking into account in particular the following criteria: performance of the existing bath maintenance system; bath lifetime; chemical and fresh water demand; wastewater flow; process throughput; operating time and purity requirement. After the evaluation on the basis of the mentioned criteria, relevant measures for each cleaning machine were worked out and the performance of one cleaning machine with the highest throughput was improved exemplary. By adapting the existing bath maintenance system (oil separator) and the addition of the used cleaning chemicals, the operating costs could be decreased by 43 %, taking into account the costs for cleaning chemicals, pure water and the treatment costs for the arising wastewater amount.

With the aim to generate a filtrate which can be reused as solvent for the release agent, ultrafiltration (UF) tests were made and critical/limiting factors defined. By using an ultra membrane test facility (tube module; PES membrane; cut-off 100 kDa; surface area 0.82 m<sup>2</sup>) the principal application of this technology could be shown, whereas an average COD reduction of 77 % was reached. The remaining COD load is mainly caused by additives (e.g. glycol, diethylene glycol) of the hydraulic fluids, which are used in the hydraulic system of the high-pressure die-casting machines. These glycolic substances cannot be removed by the technology of ultrafiltration, as their molecular weight requires a cut off size < 0.001 µm. Ethylene glycol itself is biologically degradable (BOD<sub>5</sub> = 0.6 gO<sub>2</sub>/g) (Jehle et al, 1995), other applicable treatment techniques could be distillation or vacuum evaporation (EIPPCB, 2005).

As thermal stress during the first usage can change the chemical structure of the included additives, a direct reuse of the excess release agent has to be seen critical. Furthermore, a formation of unsaturated organic compounds can arise by heat degradation of certain ingredients of the release agent. Depending on the structure of these ingredients, the formation of organic oxidation products (e.g. organic acids) may occur, which can lead to corrosion problems on the die-casting tools (e.g. casting dies) (Mueller, 1998). In the case of water soluble release agents, the water quality plays a

major role regarding negative side effects to the product quality and to the used die-casting tools. Therefore, the mentioned limiting factors have to be considered within the conception phase to design practical and adequate process water reuse measures. In the presented case, a solution was worked out, which includes the treatment and reuse of 18 % of the partial effluent of the die-casting line. Thus, a maximum tolerable amount of 25 % of the required water demand for the preparation of the water soluble release agent was defined. The economical advantage is mainly caused by the reduction of the environmental relevant costs in connection with the existing end-of-pipe technology and wastewater discharge system.

#### **4. Conclusions**

Considering the resources energy and water, the individual influences between sub-processes were investigated and limiting factors for a successful and extensive implementation of optimisation measures were worked out. It could be demonstrated that the areas of heat recovery and process water reuse are closely connected and that optimisation measures within one area have an immediate effect on the whole system. Therefore, an intelligent combination of technology and system optimisation is the basic requirement in order to develop practical optimisation concepts through a systematic approach within complex production systems. However, when working out optimisation measures to retrofit existing processes, the maximum efficiency is influenced through a variety of sub-processes, which limit the economical implementation potential as a whole. Thus, in many cases far-reaching adaptations of sub-processes have to accompany these optimisation measures, to use e.g. the maximum potential of the available waste heat for heat recovery measures. Furthermore, the usage of process auxiliaries has far-reaching effects on process water reuse measures and therefore to the possibility to minimise the wastewater flow.

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