Institute of Materials Science – IWT Bremen

The Foundation Institute of Materials Science (Institut für Werkstofftechnik IWT) in Bremen is a leading institute for applied research and development in the field of metal working and metal processing. The IWT is a foundation under private law, founded by the AWT (Association for Heat Treatment and Materials Science) and the federal state Bremen. Majority of its funding the IWT gets from contract research and direct orders from industry and by national and international research projects funded e.g. by the DFG, AiF/ BMWi, BMBF, EU commission and others. With more than 170 employees the IWT develops technologies that will be used in future metalworking and in industry. With a broad range of technical equipment at service, the main purpose of the IWT is to solve particular metalworking issues and to combine the results with basic research as well as applied industry research.

The IWT emerged from the former Institute of Hardening Technologies in Bremen and is an institution with a long research tradition of more than 60 years. Unique in Germany, the IWT unites three major scientific disciplines:

- Materials Science (Prof. Dr.-Ing. Hans-Werner Zoch),
- Process Technology (Prof. Dr.-Ing. habil. Lutz Mädler) and
- Manufacturing Technologies (Prof. Dr.-Ing. habil. Dr.-Ing. E.h. Ekhard Brinksmeier).

The IWT-directors and department heads are also professors in the Production Engineering Department of the University of Bremen, which combines research and teaching and enables also future engineers to benefit from new materials research results. The Bremen Institute for Materials Testing (MPA) is affiliated with the IWT and sets additional focuses in the field of materials in building and construction. The interdisciplinary cooperation ensures innovative high level results in a short period of time. Located in the science park of the University of Bremen, the IWT’s know-how is supplemented through close networking with other research institutions and other faculties. Characteristic for this are the DFG’s (Deutsche Forschungsgemeinschaft) several Collaborative Research Centres, which the IWT is or has been in charge of. The Technology Broker Bremen (TBB), which was founded with some additional research institutes in Bremen, secures the efficient transfer of all research results.

Below you will find some examples of the joint research focal points of the IWT. These were processed by the three main departments, each with their own specialized focus:

- the AiF-Leittechnologie initiative project EcoForge for High-Performance Components,
- the Research on Metalworking Fluids in projects BRAGECRIM-EPM and ERCCoolArt as well as
- the Collaborative Research Centre SFB – Distortion Engineering.

A complete overview with an extensive bibliography as well as contacts for each subject can be found under this link: www.iwt-bremen.de.

**RESOURCE-EFFICIENT PROCESS CHAINS FOR HIGH-PERFORMANCE COMPONENTS – ECOFORGE**

The research project “EcoForge – Resource efficient Process-Chains for High Performance Components” of the leading research organization AWT has been funded by the German Federation of Industrial Research Associations “Otto von Guericke” e.V. (AiF) since November 2010 with the idea of developing “leading technologies for small and medium-sized enterprises” within the program to promote industrial research and development (IGF) funded by the Federal Ministry of Economics and Technology (BMWi). In addition to the three departments of the IWT, some other university research institutes are involved in the research cooperation: the Department of Ferrous Metallurgy (IEHK) at the RWTH Aachen University, the Institute of Metal Forming and Metal Machines (IFUM), and the Institute for Materials Science (IW) at the Leibniz University of Hannover, and the Institute for Metal Forming Technology (IFU) at the University of Stuttgart.

The further development of a forging process chain from the forming process up to the final heat-treated component is the focus of the EcoForge project. The main purpose is to produce components with excellent mechanical properties with the help of resource-efficient process chains.

An expedient inspection of the processes during the project is carried out via two variations of the process control: on the one hand with precipitation-hardened ferritic-perlitic steel (AFP) and „high ductility bainite” steel (HDB) and on the other hand with case-hardened steel.

The new process chain aims at obtaining intended performance characteristics of the component directly based on the forging heat with a possible expansion of the previous application limits of the material. To increase these application limits beyond the potential of currently used AFP-steel, a so called HDB-steel is investigated, prior...
to its market launch. Based on the forging heat, components made from the HDB-steel should exhibit a full bainitic microstructure. It is also additionally investigated to what extent low-sulfur AFP-steel can be better processed through hot machining by utilizing already existing energy/process heat.

Next to the adjustment of the final microstructure, processing microstructures can be adjusted by the controlled quenching of the forging heat which for example are to be case-hardened later (gear wheels, shafts, bearing rings). The use of case-hardened steel with bainitic microstructure also allows to significantly reduce the effort of hard machining as well as to save other resources (for instance in addition to the savings of the annealing) by reducing the process steps. The controlled quenching from the forging heat aims at obtaining a defined structure with a good machinability, which is needed in particular for surface-machining or deep-hole drilling. The three departments of the IWT are collaborating to optimize this step of the process-chain. The Materials Science department validates the microstructure for high machinability used by the Manufacturing Technologies department and collaborates with the Process Technology department on the development of a spray field ensuring a controlled quenching of the component from the forging heat.

Main targets of the EcoForge project are the reduction of the time and energy used for the heat treatment and the reduction of the deformation forces through the use of the process heat. The use of the process heat for heat treatment significantly increases the energy efficiency in the manufacturing process as uncontrolled quenching and frequent re-heating of the components are avoided (Fig. 1). The integration of the heat treatment in the process chain of high-performance forged components aims at quenching the component in a flexible air-water spray nozzles array. The spray field providing the controlled quenching of the components is designed using the relevant heat treatment process parameters corresponding to the material properties for the chosen applications (Fig. 2). The spray field is combined with the recently awarded microstructure-sensor from the IW University of Hannover in cooperation with IWT. Afterwards a forging at elevated temperatures significantly reduces the forces acting on the forming while simultaneously guaranteeing a strain hardening in the component, thus positively influencing the characteristics of the component. The low machinability of bainitic microstructures is compensated through hot machining (machining at elevated temperatures) directly from the forging heat in the process chains.

**METALWORKING FLUIDS IN MACHINING PROCESSES – COOLART / BRAGECRIM**

Metalworking fluids (MWF) are used in the metalworking industry in a multitude of manufacturing and productions processes. MWF are often formulated as emulsions, in which different additives are added to the system to increase the process performing. The MWF function is to reduce the friction between the workpiece and the tool (lubrication), to dissipate the friction generated heat (cooling) and remove the generated chips. Due to mechanical, thermal, chemical, and biological stress in the process, the physical and chemical properties of the MWF change, which may negatively affect the quality of the produced workpiece, the tool life time, and the environment. According to the current state of technology, the quality of the MWF emulsion is detected by the non-process integrated analyses. These methods are often of limited significance and require a lot of time (off-line measurement).

The IWT is trying to develop a direct MWF-quality monitoring and application in different areas with different approaches.
In the line of a cooperative project between the IWT Process Engineering and the University of São Paulo as part of the "Brazilian-German Collaborative Research Initiative on Manufacturing Technology - BRAGECRIM" funded by DFG and CAPES an in-situ monitoring and control of the quality and stability of MWF emulsions is developed, which should take place online during the process. Therefore, the turbidity spectrum is continuously detected by an optical spectrometer in the process in order to draw conclusions on the physical stability of the emulsion coolant as well as to derive necessary interventions to stabilize the coolant system (Fig. 3).

The Department of the IWT also develops technologies for MWF monitoring and basic research is achieved. This commitment is supported by the German Research Foundation (DFG) as well as the in an Advanced Investigators Grant of the European Research Council (ERC) named CoolArt. Within a project supported by the Federal Ministry of Economics and Technology (BMWi), a system for a constant, automatic optimization of the essential MWF supply parameters is developed by using the IR-ThenMo-Grind grinding wheel established at IWT, which directly measures the temperature in the grinding gap. On the basis of the temperature measurement the system should regulate the nozzle position and the MWF pressure and volumetric flow.

The microbial contamination of watermixed cooling lubricants is investigated and monitored by the manufacturing technologies of IWT with the help of the Department of Microbiology of the MPA (Fig. 4). Sediments of metal particles and chips represent a complex three-dimensional structure, which show a high surface-to-volume-ratio similar to a sponge and can therefore be colonized by a large number of micro-organisms. In low-flow areas, biofilms are quickly developed, which offer a special habitat for micro-organisms. It can be assumed that due to the high population density it is exactly in this deposition the essential processes resulting in the damage of the MWF occur. Throughout the analysis, basics for the settlement structure, the microbial diversity and physiological abilities are established. These findings will help to reduce or even prevent the disturbances during the production process, as well as clearly extend the service of the MWF in the machine tools.

In addition to the basic research, the IWT also develops methods for the monitoring and cleaning of MWF in the industry. The aim is thus to integrate gas-sensor measuring systems as monitoring sensors in machine tools. Through a qualified training, they are capable of directly indicating the state of use of MWF in real time by detecting gases which are produced as end products by the metabolic processes of microorganisms.

Moreover the researchers of the IWT are trying to solve the problem of the shavings and hard grains which remain in the MWF as remnants of the grinding tool by cleaning the MWF. In industrial practice very fine filters with a small volume throughput are often used regarding to the high demands on the surface quality of the component. Due to a frequently necessary filter change, the maintenance cost of the filter systems consequently increases. The objective of the project is to test the influence of the MWF’s particle contamination on the processed work piece and to develop guidelines for the economical design of bandpass filter system in industry.

CONTROL OF DISTORTION IN COMPONENT MANUFACTURING – DISTORTION ENGINEERING

Central problems in the production of components are the dimensional and shape changes which are characteristics of the so-called ‘distortion’. They are often associated with the heat treatment as one of the last steps of the component manufacturing. In many cases the heat treatment triggers and releases internal stresses, which are caused by the previous production steps. Reasons for the workpiece distortion may be the material homogeneity that already occurs in the steel production or during the transformation. Due to the extraordinary complexity of such operations there is a need of a long-term strategy which combines the individual aspects of overlapping process chains with a general overview. The IWT is examining this topic in a close cooperation between the main departments and partner institutions in other disciplines - which was funded from 2001 by the DFG within the SFB 570 “Distortion Engineering” in cooperation with the University of Bremen.

The reasons for the distortion occurring during the heat treatment of steel components are systematically investigated by the IWT. Therefore components, such as e.g. bearing rings, shafts and gears, are examined in their production chains. Distortion Engineering encompasses the engineer-like control of the causes of distortion, on the one hand through the construction and manufacturing of components suitable for distortion and on the other hand through the specific exploitation of existing distortion potentials for the compensation of component distortions.

The SFB 570 led to a paradigmatic change, whereas before distortion was mostly seen as a problem of the heat treatment with occasional isolated adaptation in single machining steps. In contrast, the IWT is committed to an optimization of the whole manufacturing process. Thus only the consideration of the distortion as an attribute of the whole manufacturing chain is productive. Therefore the interaction between the influencing factors of every single manufacturing step on the distortion of the work piece have to be identified,
understood in regard to their impact and included into a cross-system approach through a cooperation of all relevant technical disciplines.

The IWT applies experimental design practices for the identification of the main influences and their interaction. Extensive process simulation complements the experiments, because of the multitude of influencing parameters. In order to detect the distortion causes it is necessary to register and document the relevant influencing factors. The distortion control includes alternative processes, as well as special equipment and adapted measurement techniques for the continuous process control and targeted intervention of the relevant influencing factors. For the realization of the optimized manufacturing chain communication between all involved technical disciplines is crucial.

A fast and non-intrusive method based on X-ray diffraction was developed for the determination of material parameters of the work piece surface during the phase change and tension development during the heat treatment. The obtained data serves to understand processes, to identify distortion potential and to support the simulation and modelling in order to predict the distortion characteristics during the heat treatment.

An exemplary possibility for the distortion minimization at the end of the process chain is offered by the application of “asymmetric quenching” for the specific compensation of the distortion. By knowing the distortion potential of a work piece it is possible to apply selective asymmetric quenching by the means of an adapted flow field with flexible nozzle positions in gaseous and liquid settings. Thus, it is possible to trigger targeted large distortions on cylindrical shafts compensating the typical curve of narrow workpieces (Fig. 4). The heat transfer at the workpiece could be influenced significantly by controlled jet quenching in liquid media or by spray cooling due to the influence of the boiling film and rewetting front compared to gaseous cooling. The asymmetric quenching of circular workpieces could be achieved by a selective control of the different nozzles (Fig. 5 and 6). All three main departments of the IWT, Materials Science, Process Engineering and Manufacturing Technologies, work within this cross-system cooperation on current topics and developments in industrial production in order to accompany the change and the progress in metal processing all the way from interdisciplinary fundamental research to its application.

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