

ICFG National Report 2010

GERMANY

The German Cold Forging Group (GCFG)

In September 2003 the German Cold Forging Group was officially founded to advance the national cold forging technology and to support further development in German research. The group brings together experts from industry and academia for an exchange of knowledge and experience and it acts as one institution for the definition of new research programs. Greater goals of the group are cooperation for common research activities and the support of young scientific researchers. The group consists of **72 members**:

Cold Forgers:	40 companies
Service providers / suppliers:	13 companies
Universities:	14 institutes
Organizations:	1 (VDI)
Personal members:	4

More than 75% of the members are from or directed to the automotive industry.

The steering committee consists of:

Prof. Dr.-Ing. Dipl.-Wirtsch.-Ing. Peter Groche, Director "PtU", Technical University of Darmstadt
Tillmann Fuchs, General Manager Fuchs Schraubenwerk GmbH, Siegen
Dr.-Ing. Rainer Neher, Technical Manager, Wezel GmbH, Kaltumform-Technik, Frickenhausen

Additional advisory members are:

Prof. Dr.-Ing. habil. Ulf Engel, Lehrstuhl für Fertigungstechnologie (LFT), Erlangen
Prof. Dr.-Ing. Dipl.-Wirtsch.-Ing. Peter Groche, "PtU", Technical University of Darmstadt
Dr.-Ing. Gunther Hartmann, KAMAX-Werke GmbH & Co. KG, Homberg/Ohm
Prof. Dr.-Ing. Prof. E.h. Rudolf Kawalla, Institut für Metallformung, Freiberg
Prof. Dr.-Ing. Mathias Liewald, Institut für Umformtechnik (IfU), Universität Stuttgart
Dr.-Ing. Markus Meidert, ThyssenKrupp Presta AG, Eschen (Liechtenstein)
Dr. Ing. Rainer Neher, Technical Manager, Wezel GmbH, Kaltumform-Technik, Frickenhausen
Dipl.-Ing. Oliver Oehler, Schondelmaier GmbH Presswerk, Gutach / Schwarzwald
Dr.-Ing. Hans-Willi Raedt, Hirschvogel Umformtechnik GmbH, Denklingen

In the following the highlights of research at the GCFG-member institutes are presented.

**Institute for Metal Forming Technology (IFU)
University of Stuttgart**

Flange upsetting at hollow cold forged parts

Hollow components and numerous cold forging processes for producing such tubular components and semi-finished products are part of everyday business in cold forging companies. However there are still problems upsetting flanges on hollow parts. The wrinkle formation on the inner surface of a hollow part during the free-stage upsetting process represents such a significant process limit. This kind of failure considerably decreases the component strength, especially with alternating loads. Also the failure detection on a workpiece with a large length to diameter ratio is difficult during manufacturing processes, which makes a robust process necessary. Within the scope of this project, technological measures, to avoid wrinkling and exceed actual process limits, are examined by a correspondingly extensive range of parameters.

Working group for cold forging of aluminium alloys

The working group called “Cold Forging of Aluminium Alloys” has been established in October 2006 through encouragement of 13 industrial organisations. Group meetings are held at least twice a year and teamwork since 2006 is strongly focused on various research tasks: practical testing of a new developed raw material test, material data collection of semi-finished raw material, investigations on tribology of aluminium cold forging processes and optimisation of specific modelling for FEA purposes.

Influence of slug surface for cold forging of aluminium alloys

Cold forging process of aluminium alloys shows a different behaviour compared to steel. Due to material specific characteristics strengthening behaviour and tribological system of aluminium alloys is distinctively different to steel materials. The adhesion affinity of aluminium on the tool surface leads to strong aluminium adherences after a few strokes, which make ongoing forming sequences not possible anymore. The intention of these investigations is to analyze the influence of the slug preparation process (shot blasting) on slug surface characteristics (topography and skin hardness). The results are going to be used to select a lubricant, which is adapted to the characteristics of the slug surface. The first step of this investigation is to test two differently prepared slug charges with 4 different lubricant types.

Investigations on lateral extrusion of hollow specimen at elevated temperatures

Lateral extrusion of cross-wise parts with hollow journals using high-strength steel is limited by formability of the material at room temperature and by tool loads. A combination of hollow lateral extrusion and double-sided backward cup extrusion at the range of warm forming temperature expands the process limits. At first, process limits of warm lateral cup extrusion of steels with high carbon and alloy content are determined by experimental investigations. Long-term objective of these investigations is the development of basics for the process and tool design of this and similar lateral extrusion processes (also with other asymmetrical shaped elements) of high-strength steel.

Investigations on Bending of Thick “First Wall” Cooling Plates

Test-Blanket-Modules (TBM) are components of the inner wall of a fusion reactor and have the task to convert the kinetic energy of neutrons into heat. Due to the high temperatures inside a fusion reactor a TBM is provided with cooling chanals. This study examines the fabrication of such a TBM with cooling chanals by free die bending. At first, the flow curves of the material have been

determined and investigations about the damage behaviour were accomplished. The material data was used for FEA bending trials. After validation of the deformation in FEA and bending tests an optimization of the bending process has been done regarding the lowest deformation of the cooling channels.

Bulk metal forming at elevated temperatures – Extrusion of steel between room temperature and 500°C

By forming in the temperature range below (industrial) warm forming temperature a combination of the advantages of cold and warm forming under economically optimal conditions is intended. Temperature range beyond blue brittleness between 300 °C and 500 °C for steel, which is characterised by a high ductility and low yield stresses, is of particular interest. In addition to an increase of formability forming at elevated temperatures leads to a decrease of tool load and an increase of tool life time respectively. Due to lacking experiences within forming at elevated temperatures this study is based on the three work packages tribology, technological material properties and process investigations. First package dealing with tribological investigations is already completed and showed that commercially available lubricants for cold forging and lubricants specifically developed for this temperature range are well applicable in a single-stage forming process. Lubricants reliability in a multi-stage process will be examined after completing second package dealing with material properties.

Investigations on hollow lateral extrusion of tubular raw material

Bulk metal formed workpieces with tubular raw material and additionally hollow shaped elements show an enormous lightweight construction potential. Areas of application of such geometrically new formed parts are automobile industry and mechanical engineering. The basics of the process for hollow lateral extrusion of tubular raw material are incomplete. In a first test series of forming trials the feasibility of the process has been proven. Resuming the interrelations and the factors of influence between processing, geometry characteristics and tool design are analyzed in cooperation with the IUL (Institute of Forming Technology and Lightweight Construction, University of Dortmund) on the basis of coupled experimental and numeric investigations.

Cooling and lubricant concepts for rotary swaging machines

Due to the high temperature in the forming area, high relative velocities between tools and high pressures the entire tribological system of a rotary swaging machine provides a demanding cooling and lubrication concept. These requirements actually are satisfied by an extensive use of oil-based lubricants. The first step in this project is to determine reference temperatures for the current state of cooling and lubrication concept using oil-based lubes. Subsequently the oil-based lube is substituted by a water-base lube used in turning and milling processes, which can be fed in less quantity because of a better cooling characteristic. The main goal is to develop a concept for dry rotary swaging process.

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- [Rud10] Rudolf, S.; Liewald, M.; Felde, A.: Hohl-Quer-Fließpressen von Rohrförmigen Rohteilen – ein neues Verfahren zur Herstellung von Leichtbaukomponenten. In: Buchmayr, B. (Hrsg.) XXIX. Verformungstechnisches Kolloquium, 27. Februar bis 02. März 2010, Planneraalm, Steiermark, S. 59 – 65.
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- [Rud09] Rudolf, S.; Felde, A.; Liewald, M.: Enhancement of Forming Limits of Magnesium Alloys by Lateral Extrusion. In: Akkoc, M.; Budak, E.; Firat, M.; Kaftanoglu, B. (Edit.): 5th International Conference and Exhibition on Design and Production of Machines and Dies/Molds (2009), S. 81 – 84, Kusadasi, Turkey, 2009.

Institute of Metal Forming and Metal-Forming Machines Leibniz Universität Hannover

Local Strain-Hardening in Forging Components

One topic of the collaborative research center 675 (CRC 675) "Creation of high strength metallic structures and joints by setting up scaled local material properties" is the investigation of martensite evolution in metastable austenitic steels by using massive forming processes. The martensite formation in metastable austenitic CrNi-steels is mainly affected by alloy elements, temperature, state of stress and degree of deformation. Different forming processes, e.g. upsetting test and backward cup extrusion were tested, varying the mentioned parameters. The content of martensite in the specimens was correlated with the forming parameters. It was figured out that the temperature is a significant parameter. Especially below ambient temperature the formation of martensite increases considerably. Furthermore a tool for a combined hot and cold forging process was developed for the production of load adapted components with locally optimised properties. By FE-Analyses, which supported the development process, a local martensite evolution was predicted.

Massive Forming of Complex Structure Components with Selective Local Properties by Means of Superimposed Hydrostatic Pressure

Another topic of the CRC 675 is the development of an innovative tool concept to increase the forming capacity of low ductile materials by means of a superimposed hydrostatic pressure. By increasing the formability of the workpiece, larger local plastic strains can be achieved and forming steps are reduced. Therefore, this process offers new design possibilities with locally adjusted structure or structure component properties, tailored to their technical applications.

First results reveal highly increased formability at superimposed pressure of 85 MPa for workpieces from thermosetting alloy AlSi1MgMn (EN AW-6082). In comparison tests with self-hardening alloy AlMg4.5Mn0.7 (EN AW-5083) the formability is less increased. As a general tendency the self-hardening alloys show a lower increase in formability when forged under superimposed pressure. By evaluating damage models in finite element models the damage occurring in cold forming processes under superimposed hydrostatic pressure was predicted. Further investigations will cover different strain rates, degrees of deformation, aluminium alloys and pressures up to 200 MPa.

Publications:

Behrens, B.-A.; Bouguecha, A.; Mielke, J.; Weilandt, K.; Knigge, J. Verformungsinduzierter Martensit in der Massivumformung, 29. Verformungskundliches Kolloquium 2010, 27. Februar - 02. März 2010, Planneralm, ISBN: 978-3-902078-14-8, pp. 35-40

Behrens, B.-A.; Hübner, S.; Knigge, J.; Voges-Schwieger, K.; Weilandt, K. Gezielte Funktionalisierung der Martensitevolution in Blech- und Schmiedebauteilen, 7. Industriekolloquium Clausthal „Potenziale metallischer Werkstoffe lokal nutzen“, 25.-26. November 2009 in Clausthal-Zellerfeld, pp. 41-47.

Behrens, B.-A.; Hagen, T.; Mielke, J.; Knigge, J. Herstellung komplexer Verbindungselemente aus Aluminiumlegierungen durch Umformen mit drucküberlagertem hydrostatischem Druck, 7. Industriekolloquium Clausthal „Potenziale metallischer Werkstoffe lokal nutzen“, 25.-26. November 2009 in Clausthal-Zellerfeld, pp. 129-136

RWTH Aachen University Laboratory for Machine Tools and Production Engineering WZL of RWTH Aachen University

Prediction of Materials' Formability (AVIF A263)

The damage-free and economical manufacturing of lightweight, high complex vehicle components by cold forging requires knowledge about the material's formability. Damage criteria currently applied for the simulative process design are characterized by an insufficient prediction accuracy of the materials' formability. Therefore, an advanced approach is developed for the fracture prediction in cold forging processes. The approach is exemplarily developed for the case-hardening steel 16MnCr5-GKZ (GKZ = heating for globular cementite).

Environmentally Friendly Cold Forming (DFG SFB 442)

The collaborative research center 442 "Environmentally Friendly Tribosystems", funded by the German Research Foundation (DFG), aims to apply biodegradable lubricants in all parts of a machine tool. This includes the lubrication of forming and cutting processes. Within the subproject B6 "Environmentally Friendly Cold Forming" cold forming processes like extrusion, deep drawing and fine blanking are investigated. Therefore, rape oil based esters have been chemically modified so that they combine good lubricating properties of native esters with high oxidation and hydrolysis stability. Deficiencies in the tribological performance are to be compensated by the application of newly developed PVD tool coatings.

Bonder-free Cold Bulk Forming

Parallel to the collaborative research center 442 an according transfer project named "Bondering-free Cold Bulk Forming" is also funded by the German Research Foundation. The main goal of the project is, to apply the results of research of the collaborative research center 442 to industrial application. By coating the forming tools and using environmentally friendly lubricants, bonderizing of semi-finished products is no longer necessary. The experimental series are carried out by various partners from cold metal forming industries, assisted by technological expertise from WZL.

Publications

Klocke F.; Timmer, A.; Bäcker, V.: Vorhersage des Formänderungsvermögens mit dem Ansatz der Belastungsgrenzkurve. In: 4. Sommerschule Umformtechnik „Kaltumformung“. Leoben, Austria, 22.,23.06.2009

Klocke F.; Timmer, A.; Schongen, F.: Investigation of surface crack types under axial compression loading for a case-hardening steel. In: 9th International Conference on Fracture and Damage Mechanics. Nagasaki, Japan, 20.-22.09.2010 (accepted)

Bobzin K.; Bagcivan N.; Immich P. et al.: Advancement of a nanolaminated TiHfN/ CrN PVD tool coating by a nano-structured CrN top layer in interaction with a biodegradable lubricant for green metal forming. In: Surface & Coatings Technology, Vol. 203, p. 3184-3188, 2009

Klocke F.; Wegner H.; Mattfeld P. et al: Wear reduction of fineblanking tools by high performance PVD tool coating and adapted substrate preparation. In: 4th International Conference on Tribology in Manufacturing Processes. Nice, France, 13.-15.06.2010

Institute for Production Engineering and Forming Machines (PtU) Technical University of Darmstadt

Efficient algorithms for the simulation of incremental forming processes

Efficient algorithms have been developed in cooperation with the Institute of Numerical Methods in Mechanical Engineering for the simulation of incremental processes for mechanical and thermo-mechanical cases. Incremental forming processes are characterized by a relatively small forming zone moving through the work piece. Thereby similar forming steps reappear during the manufacturing. This specific property of incremental processes is used to improve the efficiency of their numerical simulation. Since the simulation of incremental bulk forming processes with conventional finite element methods is still very time-consuming, a new algorithm was developed and implemented into the FE-code LARSTRAN. The simulations of flow forming and rotary swaging processes are compared with experimental results showing a relative close match. Computational time can significantly be saved if the similarity of the forming steps is used by means of a data mapping. This is revealed by simplified incremental processes.

Development of innovative methods for the qualification of tribological systems in cold forging

Three industrial companies and the Institute for Production Engineering and Forming Machines (PtU) develop a new method for the qualification of tribological systems. On this account, two computer based tools have been used to analyse the load of forming processes and to qualify the tribological system. Additionally, the test stand design has been optimised and enhanced to identify the limits of tribological systems. Software and database can be used in combination with the new process design to plan a forming process under tribological conditions with small production capacities. Experiments will be used to validate the innovative method.

Design of a friction model for the description of tribological conditions in cold forging of semi-finished products with structured surfaces

Structured surfaces in cold forging processes are expected to provide the opportunity of decreasing process forces and wearout of tools. The main goal of this project is to define an optimized surface for cold forging processes. Therefore, new structuring methods are developed and tested. In order to develop a new friction model, predefined parameters are varied in laboratory measurements. Based on those analyses, a new flattening model shall be developed which may be used in FEM to calculate local roughness-values. By modelling the surface-roughness and surface-enlargement as local FEM-state-variables, the friction coefficient μ may be calculated locally. The numerical description shall be implemented in the FEM-systems sfFormingSFM. The transfer of the developed model to other cold forging processes is highly probable.

Development and evaluation of surface topographies for the application of ecologically optimized lubricant systems

Conventional lubricants for cold forging processes are applied in time consuming and so called environmental unfriendly processes. New lubricants based on salt-wax-layers seem to make substitution of ZnPh+lubricant dual layer tribological systems realistic. Goal of this project is to develop a methodology that enables cold forging industry to apply technologies that allow the usage of new lubricants which are ideally applied directly before the forming process. Within this project, technological, chemical and logistic aspects of the environment friendly tribological systems will be investigated. A test system will be set up and the different aspects of the system will be examined in laboratory and industrial environment.

Influence of grain orientation and grain concentration in AFP- steel- parts on the dynamic strength

For AFP steels, which become more and more important due to their low costs, the dynamic strength with special consideration of the shaping history (grain direction in the structure) is to be examined and illustrated numerically. Their competitiveness has to be increased by an applicable calculation process, which considers the entire shaping history of the construction. The influence of sulphur compounds and phosphorus inclusions on the dynamic strength has to be evaluated. Therefore, two production processes should be analyzed: rotary swaging and die forging. The results of the numerical analyses have to be compared with experimental results.

Integration of Functional Materials

In this project, the foundations are laid for the integration of adaptronic components into metallic structures by means of incremental forming methods. The connection between bearing structure and adaptronic components must make a reciprocal safe energy transmission possible, it must show a high long-term stability and, moreover, it must resist to subsequent processing operations. Incremental forming methods seem to be particularly attractive for this integration task because on the one hand they manage the task without additional joining parts and are able to solve joining and forming tasks at the same time. On the other hand, the forming and the local component loads can be largely influenced by means of the selection of the tool paths. In this type of integration, the susceptibility of the adaptronic components is a major challenge. Forming methods are in the focus of the studies of this project, such as rotary swaging, flow forming as well as orbital forming.

Production of UFG materials by rotary swaging

Materials with ultra-fine size grains produced by severe plastic deformation (SPD) have promising properties, such as a combination of high strength and ductility, which makes them interesting for many technical applications. Despite the broad spectrum of potential applications, the commercial use of such materials was very limited so far. The reason for this lies primarily in the high production costs of the ultra-fine grain (UFG) materials.

A new severe plastic deformation method, Equal Channel Angular Swaging (ECAS), has been developed at Technische Universität Darmstadt to produce bulk UFG materials by combining the conventional Equal Channel Angular Pressing (ECAP) and the incremental forming method rotary swaging. Increasing the process efficiency is the main focus of the current studies.

Publications and oral presentations:

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Görtan, M.O.; Bruder, E.; Groche, P.; Müller, C.: New Severe Plastic Deformation Process to Produce Ultrafine Grained Materials. 13th International Conference on Metal Forming. Toyohashi, Japan: 2010

Groche, P.; Müller, C.; Görtan, M.O.; Bruder, E.: Kontinuierliche Herstellung von hochfesten UFG Drähten durch ECAS. wt Werkstattstechnik online, Nr. 10-2010

A. Abrass, F. van de Loo, P. Groche, M. Schäfer : Effiziente Algorithmen zur Simulation von inkrementellen Umformverfahren, Abschlusskolloquium zum SPP 1146 "Modellierung inkrementeller Umformverfahren", 09. Sep .2009, Bonn

Groche, P., Abrass, A.: New Algorithms for Thermo-mechanical FE-Simulation of Quasi-periodic Processes, steel research international Vol. 81, 6. Apr 2010

Abrass, A., Groche, P.: Usage of similarity in incremental bulk forming for speed up the FE-Simulation, Numiform 2010, AIP Conference Proceedings Volume 1252, American Institute of Physics, 20

M. Türk; P. Groche: Integration of adaptive components by incremental forming processes, SPIE Smart Structures/NDE, San Diego, 2010

Fraunhofer Institute for Machine Tools and Forming Technology Chemnitz (IWU)

One focus of research at IWU was the forming manufacturing of metal compounds, Al/Mg in particular. The investigation has been concentrated on the characterisation and optimisation of the product (/1/, /2/).

Significant further work of the IWU in the field cold forging of last year has concerned the targeted adjustment of material properties, sometimes locally different, with emphasis on components made of high-strength aluminium alloys. The gradient characteristic was achieved mainly by the targeted local metal forming influence and through the setting of specific microstructural constellations using severe plastic deformation (/3/-/5/).

Enormous progress has been made regarding the forming production of gear wheels. Spur gears with tooth height factors far higher than 2 could be realised at a high quality level with essential functional and economic benefit in comparison to milled pre-gearings /6/.

Important Publications

/1/ Neugebauer, R.; Glaß, R.; Popp, M.; Lampke, T.; Alisch, G.; Nickel, D.:
Investigation of mechanical and micro-structural characteristics of Al-Mg-compounds
Advanced Engineering Materials 11(2009)7, S. 568-672

/2/ Neugebauer, R.; Glaß, R.; Popp, M.; Nickel, D.:
Umformende Herstellung von Al/Mg-Werkstoffverbänden
Materialwissenschaft und Werkstofftechnik 40(2009)7, S. 506-511

/3/ Neugebauer, R.; Putz, M.; Bergmann, M.:
Lokale Hochverformung zur Erzeugung von ultrafeinkörnigen Zonen
Materialwissenschaft und Werkstofftechnik 40(2009)7, S. 512-516

/4/ Bergmann, M.; Neugebauer, R.; Nickel, D.; Dietrich, D.; Lampke, T.:
Aluminium als Gradientenwerkstoff von grob- über ultrafeinkörnig bis nanokristallin
12. werkstoffkundliches Kolloquium, 1.-2.10.2009, Chemnitz, S. 346-353

/5/ Neugebauer, R.; Popp, M.; Bergmann, M.:
Herstellung und Verarbeitung hochfester aluminiumbasierter Leichtbauwerkstoffe
3rd ICAFT und 16. Sächsische Fachtagung Umformtechnik SFU, 10.-11.11.2009, Chemnitz, S. 259-282

/6/ Hellfritzsch, U.; Lahl, M.; Milbrandt, M.; Schiller, S.:
Walzprozess und Stirnradverzahnungen
2. Symposium Praxis der Zahnradsfertigung, 22.-24.6.2009, Esslingen, S. 25-34

Chair of Manufacturing Technology (LFT) University of Erlangen-Nuremberg

Process combination for manufacturing of teathed, thin-walled functional components out of tailored blanks

Subproject A1, Collaborative Research Centre SFB/TR73 (www.tr-73.de)

Vision of the TR73 is the development of a new manufacturing technology, sheet-bulk metal forming (SBMF), that will unite the advantages of sheet and bulk metal forming processes in terms of flexibility and possibilities.

Aim of the subproject A1 is the manufacturing of tailored blanks applying an upsetting and flexible rolling process on rotationally symmetric semi-finished products. Within this process a considerable variation of sheet thickness and local strain concentrations are characteristics. At the beginning studies by FE-simulations are carried out to obtain a fundamental knowledge base of the forming process and tool design. Due to the comparatively large contact area between blank and tool, high process forces are expected, which require special forming strategies. Another objective is the development of a forming process, which combines deep-drawing and upsetting within one tool. Using tailored blanks the manufacturing of complex geometrical functional components is investigated. For the realization of catch elements and gear teeth at the border of deep-drawn parts the focus of interests is in the specific control of the material flow and tool load. Especially for gear teeth local accumulations of material are required during deep-drawing and getting upset in the same tool. This results in high contact stresses and thus, in high forming forces in general. For that purpose different process designs are developed by numerical methods and will be validated by an experimental set-up.

Forming of complex functional elements on sheet metal

Subproject A2, Collaborative Research Centre SFB/TR73 (www.tr-73.de)

The project analyzes the applicability of the new process class sheet-bulk metal forming for the extrusion of complex shape elements. This is exemplified by a gear tooth forming process, where the complex interactions between regions of high and low strains have been investigated by sensitivity analyses. It has been identified that a local increase of the friction factor in front of the gear tooth cavities contributes to a better form filling. In order to validate the simulation models by experiments, a cold forging tool has been designed. The investigation of new methods for the flow-control will be in the focus of the further research work.

Load oriented component properties for lightweight and high performance applications through efficient, optimized cold forging processes

Aim of the project is the combined and targeted use of the advantages of cold forging, e.g. strain hardening, to increase strength and optimize properties of components for lightweight and high performance applications. Within this project, a knowledge-based system would be built, representing relationships and interactions between the manufacturing parameters and the strength of the component, in order to optimize the forming process. To achieve this aim, component properties resulting from the cold forging process, e.g. hardness, residual stresses and others, would be calculated using FE-Simulations. To validate these FE-Simulations real experiments would be carried out. In parallel the impact of properties of cold forged parts on fatigue strength would be investigated.

Cold forged high performance components made of high-strength, nitrogen alloyed steels

Due to the high work hardening, nitrogen alloyed steels are suitable for manufacturing high performance components by cold forging. The distinct work hardening causes several problems, e.g. elevated die loads or problems at the ejection process of the component. The problems can be solved by using innovative tool designs and tool materials like cemented carbide. For tool design FE methods have to be used in order to assure that no positive strains are occurring at tool components made of cemented carbide, even at maximum load of the process. The FE models have to be validated by experimental data to increase the accuracy of the FE model. The validation can be done by observing the occurring forces during the process. A valid FE model is fundamental for the process- and tool design for manufacturing components of nitrogen alloyed steels.

Microforming of bulk metal components from band material

The multi-stage cold forging of bulk microparts is a process with a high production rate potential, mainly limited by handling problems between the distinct forming stages. A possible solution is seen in a bulk forming process inspired by sheet metal stamping, not requiring high performance tools like mechanical microgrippers. The results of these studies will lead up to a definition of the achievable geometries and a review of further one- and more step forming processes from the blank plane. The research is starting with the finite element simulation of single step bulk forming processes, in order to design subsequently an experimental working tool. The synthesis of these two procedures involves an optimization of the metal flow during one and more step bulk forming processes, working simultaneously on simulation and experiments; finally a theoretical overview can be produced, describing the forming potentials of also more complex geometries.

Application based multi-layer coatings for cold forging tools and their validation by innovative test procedures

The high mechanical and tribological loads, which cold forging tools are exposed to, often cause an early tool failure. The aim of the project is to achieve a considerable extension of tool life and an improvement in the surface quality of the workpiece by multi-layer coatings or nano-layer coatings, which are adjusted to the application and load. For the determination of the load on the tool FE-simulations are carried out. The friction coefficient is determined in Double Cup Extrusion-tests. In order to investigate wear resistance of the coatings, coated tools are tested in a newly developed combined punching-forward extrusion test (CPFE-test) and in industrial applications. The investigated multi-layer and nano-layer coatings reveal a higher wear resistance in the CPFE-test and in industrial applications than the mono-layer coatings. The results are evaluated, used for the enhancement of the coatings and summarized in guidelines for the application adjusted selection of multi-layer coatings.

Optimization of Tool and Process Design for the Cold Forging of Net-Shape Parts by Simulation

The project's objective is to obtain high dimensional accuracy of cold forged parts without try-out and scrap-production. Achieving high accuracy is complicated by interactions between press, tooling system and process that influence the workpiece dimensions due to elastic deformations and nonlinear effects (press drive). To determine an adjusted tool and process layout that compensates these interactions, they are considered during the tool design and process layout in FE simulation by a combined modeling of the deflection characteristic and the cold forging process. Based on a set of FE-simulations with several influencing factors varied, a parametric process model can be calculated. For the optimization of the values of the influencing factors an algorithm

was developed according to the specific behavior of cold extrusion processes. Applying the optimized settings then leads to the specified workpiece dimensions.

Functional Characterization of Tool Surfaces

In cold forging cemented carbides are often used as tool material beside high speed steels. The hard metal is machined either by grinding or by electrical discharge machining (EDM). Finally the tool surface is polished, because the structure of the tool surface has a significant influence on the dominating failure mechanisms wear and fatigue. The process chains grinding-polishing and EDM-polishing have different impacts on the surface properties of the tool. In this project the surface properties and their influence on the tool behavior in the forming process will be investigated and characterized by using 3D surface parameters. Aim of the project is to gain knowledge for an optimized cemented carbide tool production in terms of production costs and tool behavior in the forming process.

Publications:

- Eichenhüller, B.; Engel, U.; Geiger, M.: Microforming and investigation of parameter interactions. *Prod. Eng. Res. Devel.* 4(2010)2-3, 135-140
- Eichenhüller, B.; Engel, U.: Investigation of effects and parameter interactions in metal microforming processes. In: SAILE, V.; EHMANN, K.; DIMOV, S.(Hrsg.): 4M/ICOMM 2009, Proc. Global Conf. on Micro Manufacture (incorp. 5th Int. Conf. on Multi-Material Micro Manufacture 4M and 4th Int. Conf. on Micro Manufacturing ICOMM), Sep 23-25, 2009, Karlsruhe, Germany, pp 245-248, published online by ECO Professional Engineering Publishing Ltd. DOI 10.1243/17547164C0012009048
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