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RESEARCH PROFILE OF THE FRAUNHOFER IWU AND SELECTED PROJECTS

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ABSTRACT: The survey paper begins with an introduction of the Fraunhofer Foundation FhG. The research profile of the Fraunhofer Institute for Machine Tools and Forming Technology IWU is illustrated by selected research projects in the fields of machine tools, machining, forming and systems technology. The production of fine-grain aluminium alloys with gradient properties and the production and processing of intelligent semi-finished metal sheets by use of piezo-ceramics are among the projects sponsored by the German Research Foundation DFG. With regional sponsoring within Saxony further research in the field of press hardening (hot sheet metal forming with subsequent hardening) is possible. Opportunities for cooperation are presented.

KEYWORDS: high strength aluminium alloy, hot forming, thermomechanical treatment, piezo-metal composite

1 INTRODUCTION

The aim of the Saxon-Czech higher education in engineering initiative is the advancement of cross-border scientific cooperation in field of materials engineering. This aim motivates the present article where the competencies of the Fraunhofer Institute for Machine Tools and Forming Technology IWU in machine tools, shape cutting chipping, forming and system technologies are presented. Opportunities for possible cooperation activities are presented.

2 THE FhG AND THE WGP

The Fraunhofer Foundation FhG encompasses 60 institutes with more than 18.000 employees and a budget of 1.66 billion euro. The institutes are organised into multiple fields of research including life sciences, materials, optics and production engineering. Several FhG institutes are members of the German Academic Society for Production Engineering WGP founded in 1998. The membership is formed by IFF Magdeburg, IML Dortmund, IPA Stuttgart, IPK Berlin, IPT Aachen, UMSICHT Oberhausen and IWU Chemnitz. These FhG institutes have international departments in the United States, South Africa and Asia.

3 THE IWU

3.1 PROFILE

The Fraunhofer Institute for Machine Tools and Forming Technology IWU was established in 1991 with only a handful of employees. Nowadays it is formed by 400 scientists, engineers and support staff with a budget of more than 24 million euro. The facilities cover about 7.000 m² with 4.000 m² area for laboratories. They are distributed in Chemnitz and Dresden and since 2009 in Augsburg as well. Research activities are conducted in close cooperation with the Chemnitz University of Technology and other FhG institutes, machine tool producers and German automobile manufacturers and suppliers.

3.2 COMPETENCIES

3.2.1 Machine tools

The competencies of the IWU include concepts for machine tools as well as development of precision components. In the area of machine tools handling systems, parallel kinematic mechanisms and thermal behaviour optimisation strategies are developed with support of FEM simulations. Concepts for lightweight design are implemented with the application of metal foam structures in machine tool components and the generative production of lightweight structures. Hydraulic systems are designed by experimental and simulation methods.

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3.2.2 Mechatronics

The main emphasis is adaptronics. The IWU deals with active materials like memory shape materials and piezo ceramics. The goal is the development of intelligent components by use of sensor and actuator functions. The behaviour of these components is analysed and optimised. In medical fields adaptronic components are produced for healing processes and implants. In addition, research activities focus on the design and control of parallel kinematic mechanisms, redundant machine tool axes and calibration methods. It includes data handling using classification methods and image processing.

3.2.3 Machining technology

The main focus is the conception and optimisation of cutting tools and tool coatings beginning from the modelling and simulation of cutting technologies. Shapeless clamping is being developed for the handling of micro components. Cutting process and tool behaviour monitoring is an important activity. Effort is invested in the further development of cutting processes including ultrasonically assisted deep drilling and dry machining. A special emphasis is micromachining. In this area special tools and manufacturing of functional surfaces are being developed for medical, optical and special automobile applications.

3.2.4 Forming technologies

The sheet metal and bulk forming technologies constitute the main research activities at the IWU. In the case of deep-drawing, optimisation is performed by process control methods. The extension of forming boundaries is another scientific aim. This can be attained by using high speed forming and targeted heat management during and after the forming process. Special fields are hydroforming technology and blanking. With the application of generative tooling it has been possible to improve high mix-low volume manufacturing. Forging, cross rolling and spin extrusion bulk metal forming technologies have been optimised. The use of alternative materials like high strength steel, magnesium and titanium—particularly challenging for forming operations—are also being investigated.

3.2.5 Systems technologies

The domain of systems technologies encompasses the development of facilities and components, joining, and assembling. In automobile manufacturing thermal joining and joining by forming are broadly used. New technologies in dieless joining by forming (clinching) and hydro-joining are being developed at the IWU. Process monitoring by acoustic emission (AE) and quality inspections are assisted by strength of materials investigations, evaluation of cross-sections and investigations of the effect of geometric parameters on joint strength. In addition, error diagnostics and remote services based on e-services are being developed.

4 SELECTED PROJETS

4.1 MATERIALS WITH GRADED PROPERTIES

Lightweight construction often makes use of high-strength materials throughout. A smarter approach is the generation of gradient material properties in the semi-finished products. By using severe plastic deformation in a global (extrusion) or incremental (rolling) manner it is possible to obtain gradient properties in the cross section of a bolt or screw, for example (see Figure 1 and **Figure 2**).

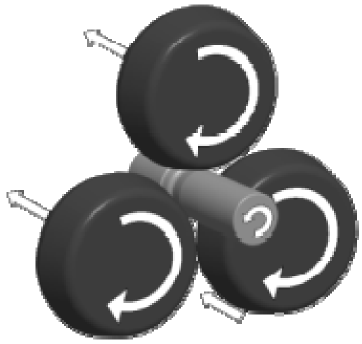

Figure 1: Spin extrusion (scheme)

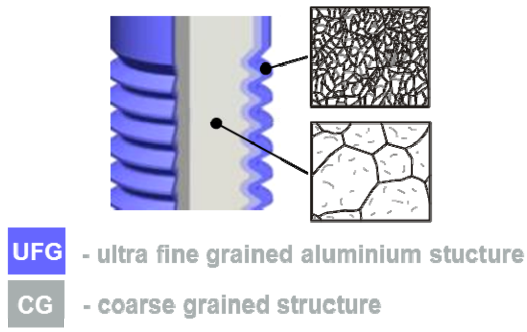

Figure 2: Possible gradient grain size by using an incremental forming process like spin extrusion

The investigations have shown that spin extrusion is a suitable method for producing continuously variable grain sizes in the range of approximately < 1 - 50 µm [1]. As a result the hardness was changed gradually from 110 to 130 HV1. Efforts are being focused on tool geometry and machine kinematic optimisation.

4.2 SMART SEMI-FINISHED PARTS FOR SHEET METAL STRUCTURES

In many fields and particularly in the automotive sector lightweight concepts are gaining importance. The motivations include depletion of non-renewable resources, passenger comfort and safety requirements. By use of lightweight concepts in the car body—which entails about 30% of the total weight of the vehicle—the use-phase efficiency can be significantly improved. Furthermore they bring positive effects on driving dynamics.

An increase in the strength of sheet metal materials enables a reduction of the thickness of auto body parts and associated weight. However, thickness reduction can lead to an unacceptable noise, vibration and harshness levels. To cope with this problem, adaptronic devices are being investigated on order to locally influence stiffness. Sensors and actuators based on piezoceramics, for example, allow the detection and reduction of unwanted vibrations. Currently the production of piezo-modules like Macro-Fibre-Composites (MFC) involves a lot of manual work. For high-volume production a new process chain is required. IWU has developed a method that allows the application of piezomodules on mass-produced 3D-formed parts. The integration takes place before the forming operation. The modules are embedded with a semi-cured adhesive to reduce tensile stresses in the brittle piezo components due to contact pressure and friction between blanks and module during the forming operation (see **Figure 3**).

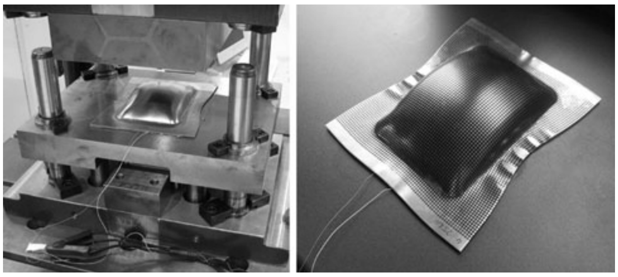

Figure 3: Deep-drawing rectangular cups: tool system (left), cup specimen (right)

The functionality of the specimens is characterised by the measurement of module capacitance during the forming process as well as actuator and sensor tests after forming. A prediction of the locations of module degradation and the main influences are determined by numerical methods. It has been shown that the functionality of integrated modules can be fully maintained for bending radii down to about 10 mm in the case of rectangular cups with double curvature of 100 mm and 250 mm. Axisymmetric specimens formed with a punch radius of 50 mm showed damage and radii below 25 mm caused significant damage until breakdown occurred contingent upon the draw depth (see **Figure 4**).

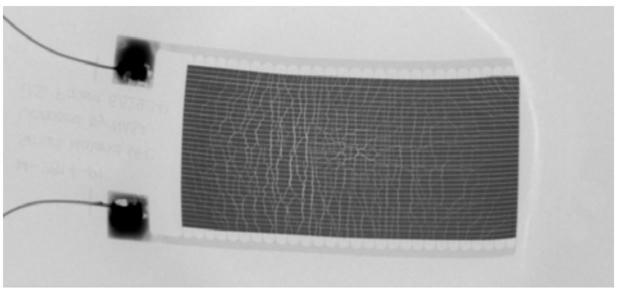

Figure 4: X-ray analysis of axisymmetric specimen with a radius of 25 mm [2].

4.3 PRESS HARDENING

Energy efficiency in production is an important goal to reach sustainable worldwide energy demand and therewith reduce carbon-dioxide emissions [3]. In this context the energy efficiency of the press hardening process is under investigation. Hardenable austenitic steel (22MnB5) has to be hot formed and afterwards hardened by cooling from the tools. The aim is to generate localized properties by suitable process parameters. Requirements of the formed parts include a high level of rigidity and ability to absorb impact energy in the event of a crash. To this end, emphasis is being placed on tool design aimed at improving process stability and part quality (see **Figure 5**).

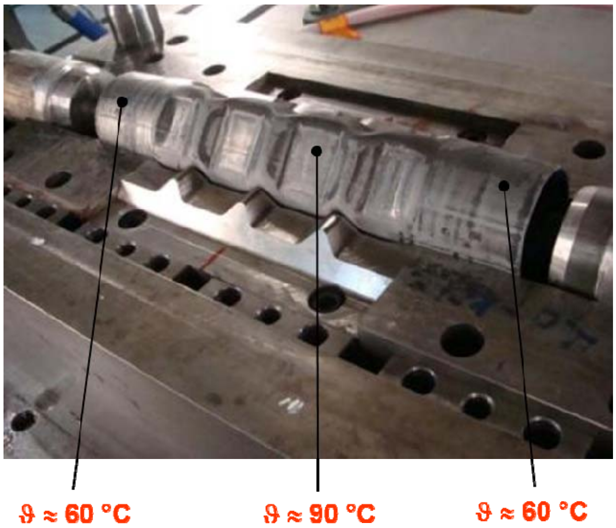

Figure 5: Distribution of temperature in a press hardened hydroformed part (calibration pressure: 700 bar)

Hardness measurements of the hot formed tube showed the differences in strength in various locations. The tensile strength varied from 1450 to 1610 MPa with an initial strength of 550 to 600 MPa (see **Figure 6**)

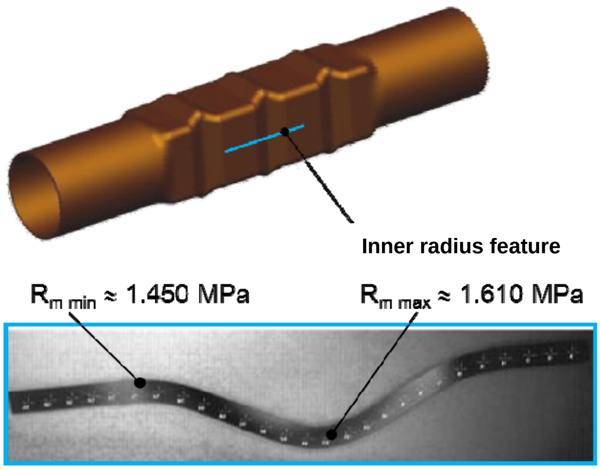

Figure 6: Distribution of strength at the formed and partially formed tube

Research has been conducted to assess the influences of workpiece-tool heat conductivity and tool temperature on the gradient properties of the formed sheet metal. Induction, conduction and radiation heating methods have been investigated (**Figure 7**).

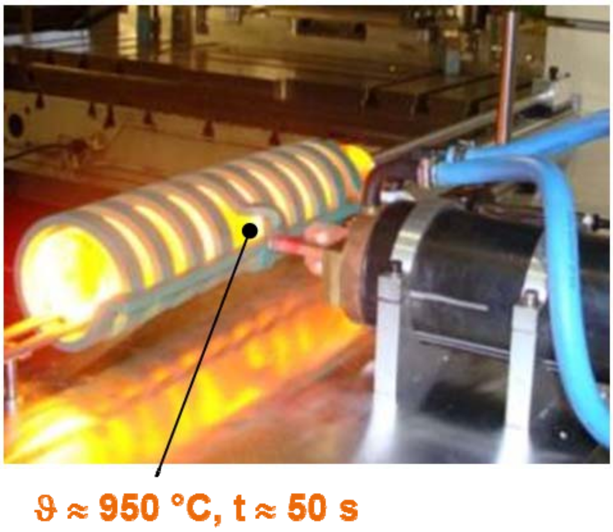

Figure 7: Inductive heating of the tube

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