



Innovations in forming technologies

P. Kurka*, F. Schieck

Fraunhofer Institute for Machine Tools and Forming Technology IWU,
Reichenhainer Str. 88, 09 126 Chemnitz, Germany

* Corresponding e-mail address: petr.kurka@iwu.fraunhofer.de

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ABSTRACT

Purpose: of this paper is the research of implementation of lightweight materials (aluminium, magnesium) as an important contribution for significant weight savings.

Design/methodology/approach: Higher process stability, improved material exploitations, and generally shortening of process chains are the most important aims of Fraunhofer IWU. The requirements of the future car ask for lightweight construction concepts, in which materials, design, and manufacturing processes harmonize optimally. Therefore, Fraunhofer IWU researches on forming and joining technologies in order to achieve the optimum usage of high-strength steels, aluminium, magnesium, and fiber composite materials.

Findings: New forming technologies as press hardening or electromagnetic forming (EMF) bring positive effects by resource efficiency and energy savings. When developing new materials, it is important to design the whole process chain according to the specific material properties.

Practical implications: Press hardening offers an effective method of forming high strength steels. EMF is a high-speed forming technology applicable for shaping, joining, and cutting electrically conductive sheet metal or hollow profile components.

Originality/value: The usage of lightweight materials is only reasonable when their mechanical characteristics such as stability, stiffness, and temperature resistance are better than those of classic steel. The same is true for the material and production costs.

Keywords: Lightweight; High-strength steel; Press hardening; Electromagnetic forming

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METHODOLOGY OF RESEARCH, ANALYSIS AND MODELLING

1. Innovations for sustainable production

The growing demand for resources absolutely requires new efficiency technologies. To be successful in global competition, energy and material efficiency need to be integrated as one of the main economically relevant dimensions for planning, operation, and optimization strategies. Material- and energy efficiency represent

considerable potential for further cost reductions in the manufacturing industry. Fraunhofer and research partners developed and validated holistic approaches towards significant improvements of resource efficiency in manufacturing. In a four step sequence, first material and energy use have to be assessed, processes and process chains need to be optimized, and efficiency potential on the manufacturing site and beyond its system boundaries will be raised [1].

In 2012 the worldwide production of automotive main materials reached critical values (1548 million tons of steel, 48 million tons of aluminium, 16 million tons of copper, and 288 million tons of plastic). The ferrous metals achieved 62% of all material used in automotive industry, whereat the non-ferrous material (aluminium, magnesium, copper) achieved only 9%. Fraunhofer IWU sees a huge potential by using lightweight materials. The reduction of weight is one of the important tasks to reduce the CO₂ emissions of car production.

2. Application of lightweight materials

The idea of lightweight materials in automotive industry has become a synonym for industrial development. The implementation of lightweight materials (aluminium, magnesium) is an important contribution for significant weight savings. Especially magnesium alloys have been being discussed in the construction of passenger cars for 10 years. When analysing lightweight material engineering, referencing the characteristic strength values as Young's modulus (E), yielding point $R_{p0.2}$ or tensile strength R_m to the density of the materials is even more important than the absolute parameters. Magnesium is the lightest useful metal with two-thirds the density of aluminium. In the TeMaK project (Technologieplattform Magnesium-Knetlegierungen) the fundamentals for the utilization of magnesium wrought alloys in a series production were outlined. During this project, a full-scale passenger car door was manufactured completely from magnesium wrought alloys AZ 31B and AZ 61 A to demonstrate the technical feasibility (Fig. 1).

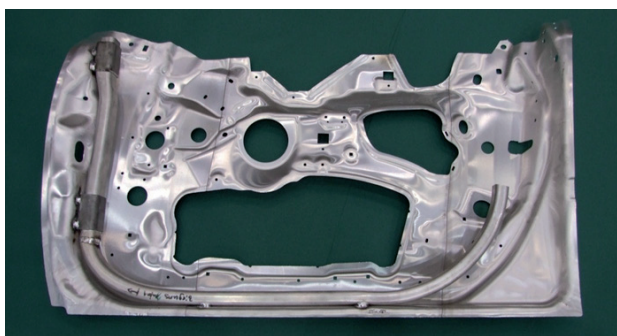


Fig. 1. The inside component of a passenger car door with a joined frame made of a magnesium wrought alloy

The door consists of outside component, inside component, frame with hinge reinforcement, and side reinforcement. The load-bearing structural frame consists of two extruded magnesium profile segments that are

joined by welding. A complex bent magnesium profile is used for the first segment while the second segment is a magnesium profile formed by hydroforming at elevated temperature and simultaneously joined with the hinge reinforcements. The complete structural frame is integrated into the inside component of the door by welding. Finally, the skin (inside and outside component are rolled sheet metals) is joined with the subassembly by folding. The focus of the research was on the tempered forming (deep drawing) and joining of the structural frames by hydroforming. In two experimental series the hydroforming connection of the magnesium profile with the hinge reinforcement was studied. Therefore, the extent to which the magnesium profile can be formed in and around the hinge reinforcement by the hydroforming process was measured. The extensions in circumference achievable without component part failure by using adequate preforming operations such as forming a circular pipe to cuboid form dropped to 25%. The reasons for this are seen in the impeded axial material feed due to the preforming geometry, the material distribution, and in the restricted material flow in the forming zone [2].

Furthermore, scientists at the Fraunhofer IWU studied whether the form closure of the magnesium profile and hinge reinforcement can absorb sufficiently high forces without moving the hinge reinforcement on the magnesium profile. Therefore, forming experiments with various means of feeding, varying calibrating pressures, and variably inclined pressure build-up curves were analyzed. Magnesium profiles were heated in two stages for the forming process: they were inductively heated to 300°C within 30 seconds followed by 30 seconds of maintaining this temperature at a lower performance level. The resulting component part geometry and the joining area were completely formed and correspondingly fully joined. Fig. 2 shows such a component.



Fig. 2. Hydroformed joined structural frame component with a hinge reinforcement

It was additionally analysed whether and to what extent occurred local thinning in the material in the area of the stamping at the form closure on the magnesium profile. The profile aligned well to the hinge reinforcement in the forming operation during the experiment without cracks or local material thinning. The maximum thinning of the experimental components was 19%, which can be assessed as non-critical.

3. Press hardening

Lightweight vehicle engineering is not only enabled by using aluminium and magnesium alloys, but also applying by high strength steel and ultra-high strength steel. In addition to sheet metal-based components, an increasing trend for implementing closed, weight and functionally optimized profiles for structural applications has been identified. Due to the complexity of components and the fact that the forming characteristics of metallic lightweight materials are frequently limited at room temperature, conventional forming processes such as hydroforming are reaching more and more feasibility limits. Unfortunately,

liquid active media such as thermal oil cannot be used for forming because depending upon the material temperatures ranging from 800° to 1,000°C are needed for hardening.

Press Hardening is an innovative technology by which advanced ultra-high strength steel is formed into complex shapes more efficiently by with traditional cold stamping. The process involves the heating of the steel blanks until they are malleable, followed by formation and then rapid cooling in specially designed dies, creating in the process a transformed and hardened material. Because of this ability to efficiently combine strength and complexity, press hardened parts accomplish in one relatively light-weight piece what would typically require thicker, heavier parts welded together in more than one process under cold stamping. Press hardening can be used for forming of sheet metals, tubes and profiles. The whole process is illustrated in Fig. 3. There is a trend towards using more high strength materials which is why the Fraunhofer Institute for Machine Tools and Forming Technology is studying materials at a high level of strength and sufficiently high elongation at rupture for their applicability in press hardening processes based on active media.

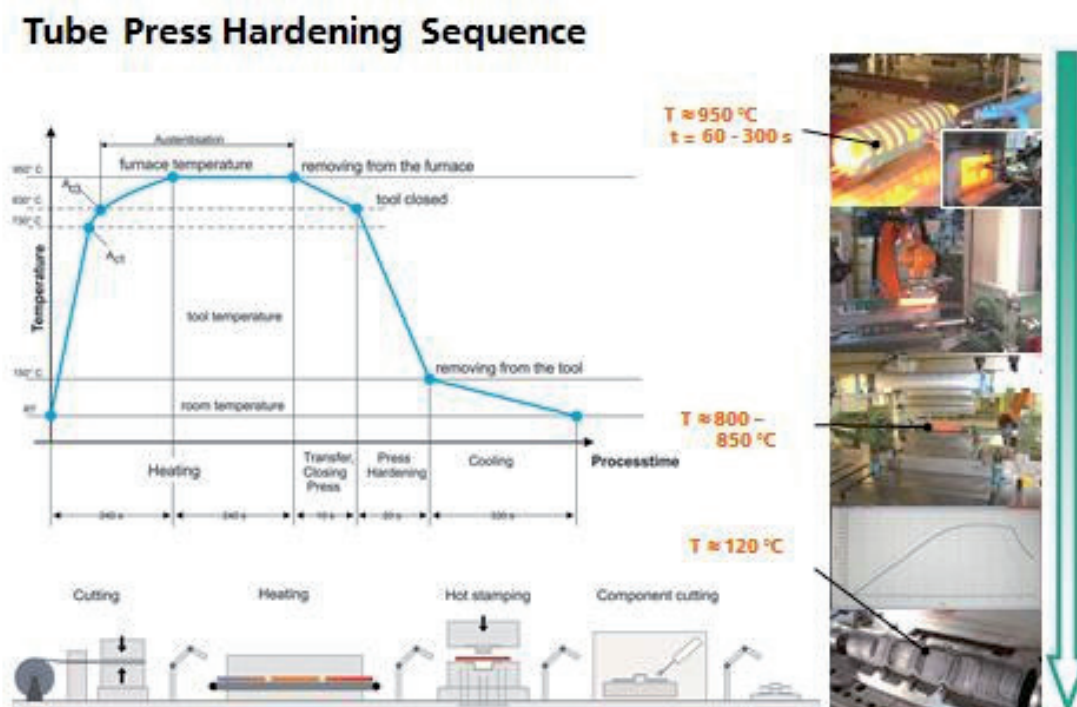


Fig. 3. Survey of press hardening of tube

In addition to the most useful 22MnB5 Fraunhofer IWU has been testing different high strength steels (LH800, 34MnB5, MW 1000L, 42SiCr). Conventional press hardening can be used to manufacture component parts that have approximately the same component part properties over their entire geometry. Unfortunately, the high level of hardness makes mechanical trimming and joining of single press-hardened parts into subassemblies much harder. Furthermore, there is a need for component parts with strength properties differing from one area to another to pass on loads and absorb impact energy. This is the reason why the Fraunhofer IWU is presently studying various technologies to achieve these tailored properties on the component part. The range of feasible solutions spans from partial component part heating to various cooling rates per component part section. Tool and process design play a significant role in the control of process chain. The demonstrator approached tool in form of shell can be used for a precise process control. The die has a special shell body to cover the cooling channels integrated in the basic body tool. The cooling channels allow an exact cooling process control due the optimal positioning.

4. Electromagnetic forming

Based on the use of new materials it is necessary to find the available forming technology for specific material properties. Fraunhofer IWU has been developing new forming technologies for applications of sheet metal and tubes since many years. Beside the conventional forming technologies, the electromagnetic forming (EMF) allows shaping new geometries by a very small energetic power consumption.

Electromagnetic Forming (EMF) is a metal working process that relies on the use of electromagnetic forces to form metallic work-pieces at high speeds. In this process, a transient electric current flows through a coil due to the sudden discharge of a capacitor bank via high-speed

switches. The coil current induces a magnetic field and a current in the nearby conductive work-piece (sheet metal, tube or hollow profile) which is directed opposed to the coil current. The magnetic field, together with the eddy current, induces Lorentz forces that drive the deformation of the work-piece. In an EMF process, the material can achieve velocities in the order up to 100 m/s in less than 0.1 ms. EMF is expected to help overcoming some formability barriers that prevent more widespread use of materials such as aluminum in lightweight structural applications. Depending on the geometry and the arrangement of the work-piece and the tool coil, this forming principle can be used for the compression and expansion of tubes or other hollow profiles as well as for the forming of flat or 3-dimensionally preformed sheet metals [3].

The typical setup for sheet metal forming consists of a spirally wound tool coil, above which the work-piece and the die, respectively, are positioned. Tubes or profile cross sections can be reduced by means of a compression coil or widened by means of expansion coils. In any case the work-piece is formed in the direction away from the tool coil. Depending on the forming process the coil is positioned inside or outside the tubular component. Thereby, the forming machine can be represented in a simplified model by an equivalent circuit consisting of a capacitor C, an inner inductance L, and an inner resistance R [4]. The main forming principles are illustrated in the Fig. 4.

EMF can be used for joining by forming similar and dissimilar material combinations. In fact joining profile shaped parts has been identified as the most promising process variant for industrial applications. Since only one joining partner needs to be electrically conductive, the potential material combinations include metal / metal as well as metal/non-metal hybrid structures (e.g. aluminum – fiber reinforced plastic-connections, copper-ceramic-connections, metal-glass-connections and others). The resulting joints can be based on interference-fit, form-fit, or – in case of metal/metal connection – even on metallic bonding realized by magnetic pulse welding.

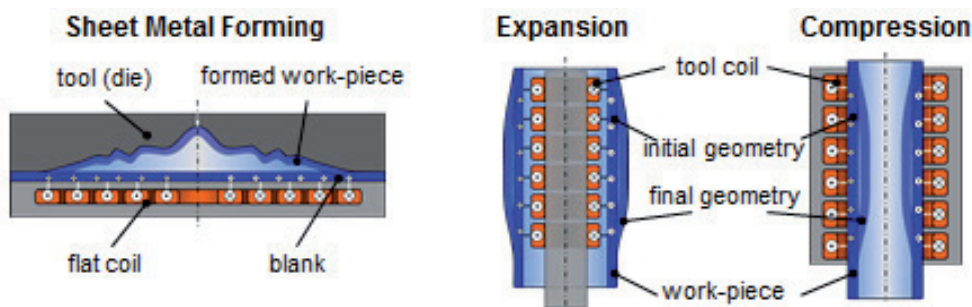


Fig. 4. Technology variants of electromagnetic forming

Some examples of joining with different materials (copper/aluminum; carbon fiber/aluminum; aluminum/aluminum; copper/carbon fiber) are illustrated in the Fig. 5. Applications of field shapers enable focusing the forces to a smaller diameter and/or length compared to the tool coil. This allows using one and the same tool coil flexibly for different forming and joining tasks. Moreover, the application of a field shaper can contribute to improving the coil lifetime, because the force acting on the coil are smaller compared to a setup without field shaper. Accordingly, the use of a field shaper supports the joining of tubes with greater wall thickness, which typically requires high forces [5].

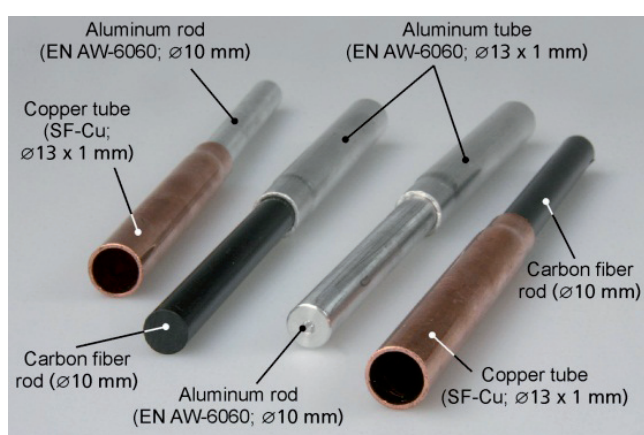


Fig. 5. Examples of joined elements

5. Summary

Lightweight materials offer a good possibility to save the weight of vehicles by constant or better performance in

comparison to the conventional steels. New technologies should be developed to shape or join the different materials. Fraunhofer has been demonstrating and optimizing in the research the possible forming techniques.

Acknowledgements

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