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FORMING TECHNOLOGIES IN AUTOMOTIVE INDUSTRY BY APPLYING LIGHTWEIGHT MATERIALS

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Abstract

The use of new materials and high strength steel is applied to the car body and structure parts based on the debate around climate changes and the demand to lower fuel consumption. The Fraunhofer Institute for Machine Tools and Forming Technology has been developing new forming technologies for applying sheet metal and tubes for many years. Hydroforming and press-hardening offer to shape new geometries at room temperature or elevated temperature.

keywords: *hydroforming, hot forming, hot metal gasforming, tempered, press hardening, elevated temperatures, steel, magnesium, profiles, tubes, lightweight, strength*

1. Introduction

The automotive industry today is constantly changing and is characterized by a sustained process of development. In particular, increased demands in terms of safety and comfort have led to a considerable increase in vehicle weights over the past few years. Further essential requirements in state-of-the-art car construction are vehicles' environmental protection and economic efficiency, which reflects a redefinition of the targets of development for current and future vehicle generations where driving down vehicle resource consumption and resource- and energy-efficient production are the focal points of the automobile industry's efforts.

One of the foremost challenges that the vehicle manufacturers will be confronted with in coming years will be a substantial reduction in fuel consumption. Here, there is not only a potential for devising highly efficient and environmentally friendly drives, but also for reducing the vehicle weight. German car manufacturers estimate that it will be necessary to drive down vehicle weight by as much as 30% in coming years without restricting the high level of convenience and safety standards [1].

This puts the idea of lightweight engineering into focus that, when taken overall, has become a synonym for a revolutionary industrial development [2, 3]. The consistent implementation of lightweight engineering concepts in vehicle structure is seen as an important contributory factor to achieving the targeted weight savings without affecting the function, safety and service life of the structure. That makes lightweight material construction one of the most essential strategies for driving down weight along with the methods of conditional, form or structural lightweight engineering [4, 5, 6, 7]. It is not the absolute strength parameters that are used for analyzing lightweight material engineering, but the characteristic figures with

reference to the density of the material such as E-module, the apparent yielding point $R_{p0,2}$ or tensile strength R_m [8, 9].

Lightweight vehicle engineering is not only determined by aluminum and magnesium alloys, but also by super high strength steel materials. In addition to sheet metal-based components, an increasing trend for closed, weight and functional optimized profiles for structural applications has been identified. Due to the burgeoning 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 increasingly running up against feasibility limits.

One approach to meeting these challenges is applying temperature as an active process parameter during the forming operation. Utilizing higher forming temperatures provides an opportunity to measurably boost the ductility of the material and therefore the forming properties in connection with it while allowing an unmistakable reduction in the yield stress and therefore the forming forces or pressures needed. Below, magnesium wrought alloys and high-strength steels will be used to demonstrate solutions and potentials for implementing tempered forming processes based on active media (T-IHU).

2. TeMaK – Series production components made of magnesium wrought alloys

Machining magnesium wrought alloys calls for some changed production routines over other material (such as steel and aluminum alloys) which is why it makes higher requirements of the thermal regime in connection with the forming processes. Therefore, in the TeMaK project the fundamentals for the utilization of magnesium wrought alloys in a series production were outlined. During this project a passenger car door on a scale of 1:1 entirely out of magnesium wrought alloys AZ 61 A was manufactured to demonstrate the technical feasibility (Figure 1).

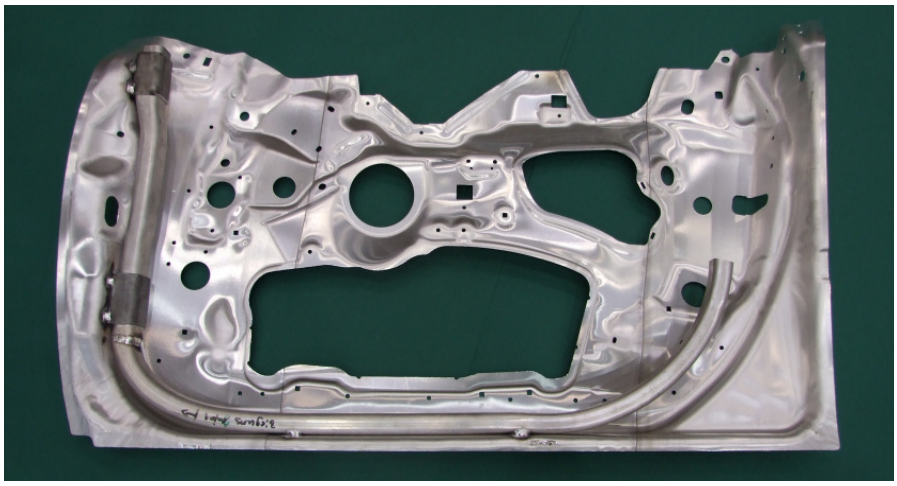

Figure 1: The inside component of a passenger car door with a jointed frame made of a magnesium wrought alloy

The structure of this demonstrator includes the load-bearing structural frame with jointed hinge reinforcements, the inside component of the door and the skin. The load-bearing structural frame consists of two magnesium profile segments that are jointed by welding. A complex bent magnesium pipe is used for the first segment

while the second segment is a magnesium profile formed by hydroforming and simultaneously jointed with the hinge reinforcements. The complete structural frame is also integrated into the inside component of the door by welding. Finally, the skin is jointed with the subassembly by folding. In the following section the focus will be on the tempered forming 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. Therefor, the extent to which the magnesium profile can be formed in and around the hinge reinforcement by the T-IHU process was measured. In preliminary studies, the circumference could be extended by as much as 75% without preforming operations under ideal geometric circumstances. The extensions in circumference that can be achieved without component part failure with 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.

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. Therefor, forming experiments with various means of feeding, varying calibrating pressures and variably inclined pressure build-up curves were analyzed. Magnesium profiles were heated up in two stages for the forming process: in the first step by using 30 seconds of inductive heating to 300°C and then 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 jointed. Figure 2 shows such a component part.

Figure 2: Hydroformed jointed structural frame component with a hinge reinforcement (forming temperature = 300°C, forming pressure = 35 MPa)

It was additionally analyzed whether and to what extent there was local thinning in the material in the area of the stamping at the form closure on the magnesium profile. The profile laid itself well onto the hinge reinforcement in the forming operation during the experiment without bursters or local material thinning. The maximum thinning of the experimental components was 19%, which means that it may be assessed as non-critical.

3. Press hardening

High strength and super high strength steels offer lightweight engineering potential along with lightweight construction via classical lightweight metals such as aluminum and magnesium. There, adjusting mechanical properties during the forming process is of particular interest. Combining hot forming with adjusting properties in one forming stage is known as press hardening and has already been used industrially in sheet-metal forming [10]. Another boost in the lightweight engineering factor was achieved by transferring this technology to closed profiles. Unfortunately, liquid active media such as thermal oil cannot be used for forming because temperatures ranging from 800° to 1,000°C depending upon the material are needed for hardening. This is the reason why gaseous pressure media are used for forming with press hardening steel materials. Figure 3 shows the scheme of such a gas forming device.

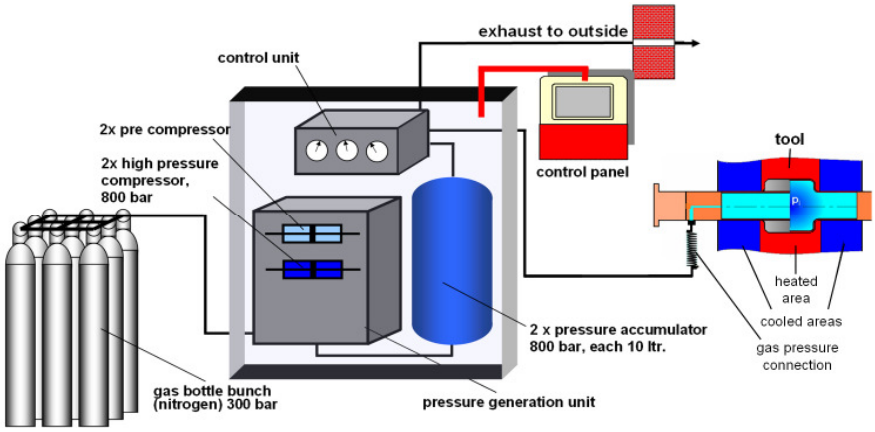

Figure 3: Scheme of a gas forming device

There is a trend towards using more super 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. The first step was the press hardening of the LH800® air hardening steel (Figure 4) from the Salzgitter AG [11].

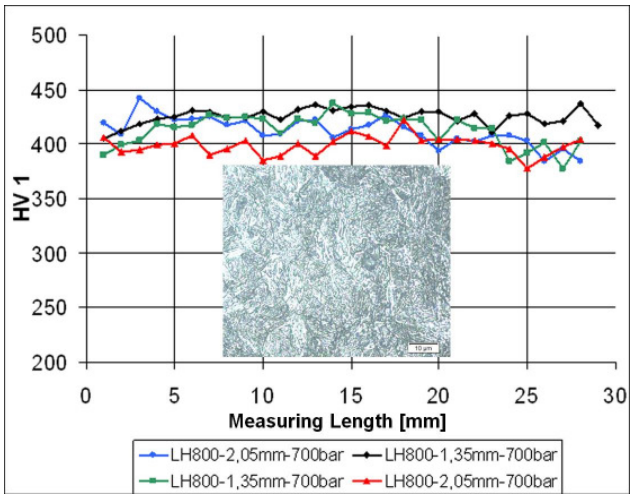

Figure 4: The microhardening distributione for IHU-press hardened LH800® and a polished section with pure martensite

The evaluation of these studies indicated engineering process limits. Not only minimal moldable radiuses were analyzed, but also the changes in hardness over the length of the part, thus determining corresponding strengths. Final strengths that are three times higher than the original material (1,200-1,900 N/mm² depending upon the material) could be documented. Furthermore, the hardness parameters were on a constantly high level over the entire distribution of the cross-section. At present, not only the LH800® air hardening steel, but also other materials such as 34MnB5 and MW1000L are studied.

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.

4. Summary

Altogether, it can be stated that temperature-supported forming operations based on active media allow a considerable shift in the limits of hydroforming. This is primarily the case with the typically lightweight engineering materials where much greater complexity can be built in component part geometries with enhanced component part properties. In particular, magnesium wrought alloys that can only be insufficiently formed at room temperature profit substantially from the boost in forming temperatures. Potentially extending circumferences by 75% and integrated forming and joining processes offer a major potential. This means that the basic development for forming and dividing structures made of magnesium have been achieved and successfully demonstrated by using the example of the convertible door demonstrator. In other words, using this material in new applications in series production is coming within our grasp.

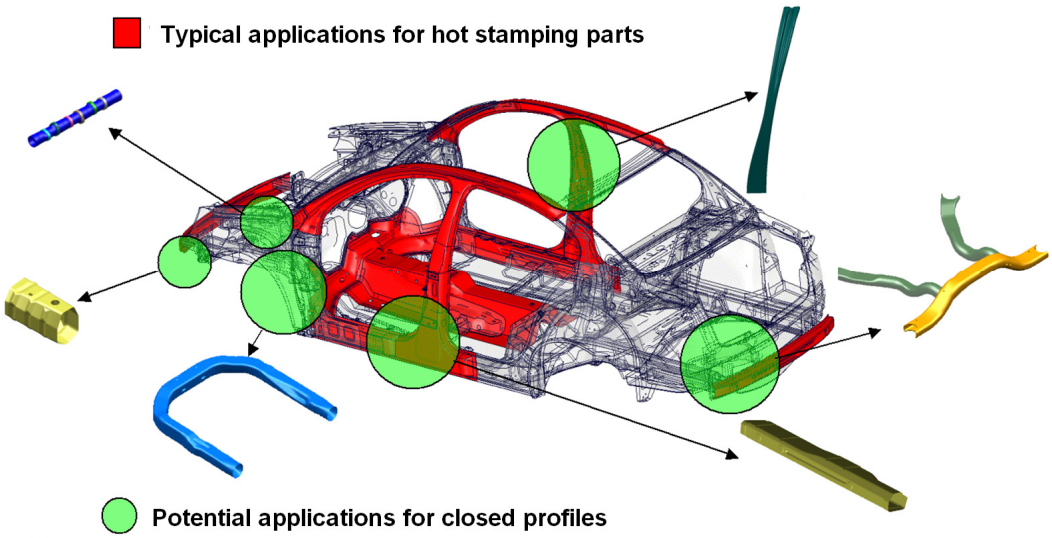

Figure 5: Potential applications for press-hardened profiles

Furthermore, Fraunhofer IWU was able to use various demonstrators to document the process capability of an integrated press hardening process in the forming process based on active media while laying the fundamentals for the optimization and further development of this combination of techniques. The combination of gas forming and press hardening techniques makes it possible to combine the excellent strength properties of press-hardened component parts with the advantages of closed complex profile components. Figure 5 shows some of the possible applications for flangeless press-hardened profile components in the car body structure. The Fraunhofer Institute for Machine Tools and Forming Technology is planning on continuing its work to transfer this technique to large-format structural components such as a flangeless B-pillar with tailored properties.

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