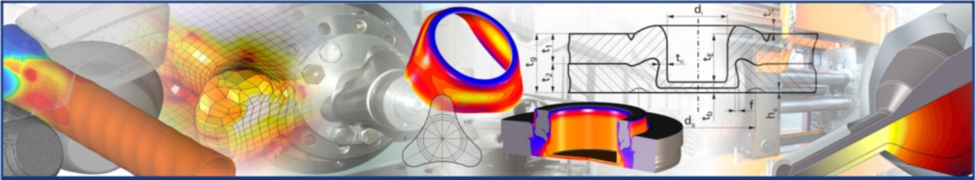

VIRTUELLE FERTIGUNGSTECHNIK

Chair of Virtual Production Engineering

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Formability of Aluminum Magnesium compounds

Motivation

SFB 692 – HALS

High-strength **A**luminum-based **L**ightweight materials for **S**afety components

Subproject B3 - *Experimental investigation and numerical simulation of the interface behavior of aluminum compounds*

In the SFB 692, subproject B3, the production of aluminum magnesium compounds by a hydrostatic co-extrusion process was investigated. The quality of these semi-finished products, especially the stability and robustness of the interface between the aluminum (AlMgSi1) sleeve and magnesium (AZ31) core, was of particular interest. The current investigations are focusing on the formability of these hybrid compounds by application of die forging. Thereby, two forging strategies are pursued simultaneously. At the first approach the work piece is formed along the longitudinal axis and at the second approach in radial direction.

Work piece

Figure 1. ASEA 12 MN hydrostatic pressing machine, CEP GmbH, Freiberg.

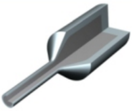

Figure 2. Simplified cross section of the hybrid strand.

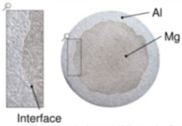

Figure 3. Cross section of a co-extruded Al-Mg compound.

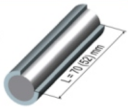

Figure 4. Simplified schematic description of the work piece.

The Al-Mg compounds were produced with the hydrostatic pressing machine ASEA 12 MN (**Fig.1**) with an initial billet dimension of Ø80(60)x300 mm. **Figure 2** shows the simplified billet with an idealized produced strand. The average length of the co-extruded strand was about 4000 mm, thereby the first ≈500 mm of strand were unusable because of the flow behavior of both materials. For following production steps it is indespensable that the interface is completely bonded as shown in **figure 3**. In previous publications the improvement of the interface quality was demonstrated [1-3]. For the die forging two different work pieces were prepared. The strand was cut into work pieces of 70 mm length for the radial forming and 52 mm for the axial forming. The relative short length of 52 mm was chosen to avoid buckling during the forming process.

Analysis

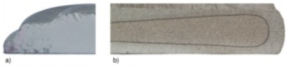

Figure 5. a) Dye penetration test for the axially formed work piece without visible damages.
b) Half cross section of the radially formed work piece with the schematic interface line.

The experimental work was performed with a mechanical press (Zeulenroda PED 100.3-S4), forming velocity 15 s^{-1}. The work pieces were preheated to 350 °C forming temperature. At the moment the dies cannot be adjusted to a specific die temperature but in the future this feature will be available. The forming processes were carried out without any lubrication to maximize the load for the compound.
Figure 5a shows the dye penetration test of the axial formed specimen and **figure 5b** the cross section of the radial formed specimen. The cross section were made by jet cutting and dye penetration tests were performed in accordance with DIN 571-1. It is obvious that the interface is very stable, ductile and has a good formability for both forming strategies (axial / radial).

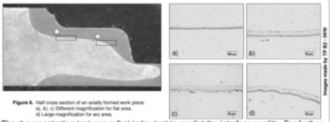

Figure 6. Half cross section of an axially formed work piece.
a), b), c) Different magnification for flat area.
d) Large magnification for arc area.

The dye penetration test was a first index test to predict the interface qualitiy. For further investigations metallographic sections were prepared. **Figure 6** shows the cross section of an axially formed specimen. **Fig. 6a**, **6b** and **6c** illustrate different magnifications of a nearly straight area (Fig. 6 top). Furthermore, **Fig. 6d** shows the magnification of the arc area (Fig.6 bottom). All images show that the interface is stable and cracks did not occure. Furthermore, the analysis of the interface thickness demonstrates that in the arc area (Fig. 6d) the interface was slightly increased.

FEM simulation

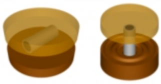

Figure 7. a) FEM model for the radial forming process.
b) FEM model for the axial forming process.

All simulations were performed with Forge2011. **Figure 7a** and **7b** show both simulation models. The real press kinematic was realized with the mechanical press template by setting the typical values. The average element edge length was about 0.8 mm and the automatic mesh adaption was triggered as well as the remeshing. Furthermore, the Tresca friction law was used with a friction coefficient of 0.8.

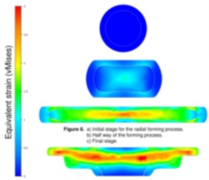

Figure 8. a) Initial stage for the radial forming process.
b) Half way of the forming process.
c) Final stage.

Figure 9. Final stage of the axial forming process .

Figure 8 shows the forming steps from initial stage (**Fig.8a**) up to the final stage (**Fig.8c**). The most interesting area for the analysis was the interface (white colored borderline). The comparison of the experiments (**Fig.5b**) with the simulations (Fig.8c) shows a good correlation for the material flow.
Previous investigations demonstrate that strain differences of the sleeve and core material is an indicator for the interface quality. Therefore, this indicator was used to analyze the interface in the simulation model. The comparison of the equivalent strain alongside the interface shows a maximum difference value of 0.5 for the radial forming process. The critical areas are the edges of the specimen. During the preparation with jet cutting some specimen were broken in this area.
Figure 9 shows the final stage of the axial forming process and confirms the results of the radial forming process. The equivalent strain differences are very low and have a similar value as the radial forming. Furthermore, the maximum values are much higher, especially the flash area which is probably the most critical area of the specimen.

Outlook

Figure 10. Geometry with representive shapes.

Figure 11. Forging die with a complex cavity.

The future work is focusing on die forging of Al-Mg compounds with industrial orientated shapes. **Figure 10** shows a geometry with different kinds of shapes which are representing important industrial used forms. Therefore, a die was developed which is shown in **Figure 11**. The die is the basis for further investigations, especially regarding the following points:

- Analysis of the influence of different forming temperatures and its effects on the formability and the interface quality
- Influence of the die temperature on the forming process
- Analysis of the material flow especially the flash development
- Investigations of the sleeve thinning by forming processes and its influence on the interface
- Analysis of multi stage processes

Acknowledgements:

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