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RATE DEPENDENCY OF INTERFACE FRAGMENTATION IN AL-MG-COMPOUNDS

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1. Introduction

Due to their high strength and low density magnesium and aluminum offer a high potential in light-weight constructions. To minimize the impact of magnesium's high corrosion sensitivity the hydrostatic extrusion process [1] is used to coat magnesium with aluminum. Thereby a bolt is pressed through a die creating a bimetal rod, Fig. 1, made up of magnesium as core material and aluminum as sleeve material, with a brittle intermetallic boundary layer between the two materials.

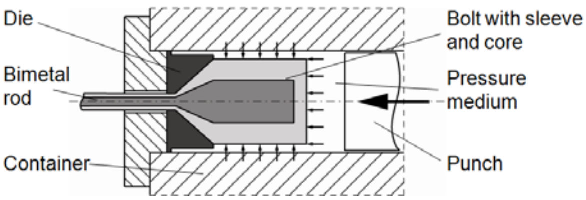

Fig. 1. Hydrostatic extrusion process [2].

Previous investigations regarding the boundary layer behaviour during the subsequent hot forging process spreading by Feuerhack [3] revealed an enormous grow of the boundary layer during the thermal treatment from 2-3µm up to 25µm and a fragmentation during the test execution. After splitting, the fragments drift apart, the basic materials refill the gaps and a new secondary boundary layer is built after contact. To investigate the fragmentation dependency regarding the rate of deformation a channel upsetting process is used with different stamp velocities.

2. Channel upsetting

The forging process spreading of the entire compound [3] is substituted by channel upsetting with a miniature specimen, Fig. 2, which is necessary to integrate the deformation process into a testing machine with a wide range of stamp velocities. All specimens are extracted by wire eroding.

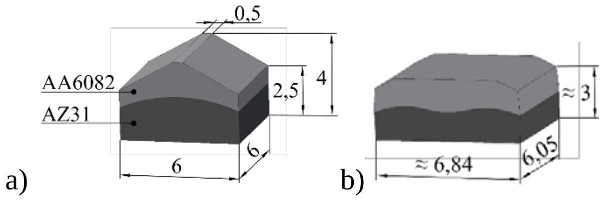

Fig. 2. Dimension of the specimen a) initial state b) deformed state.

The channel upsetting device, Fig. 3, is installed in a 50 kN INSTRON hydraulic testing machine with a gas heater using air as the transfer medium to achieve a device and specimen temperature of 300°C. Thermal isolation is attained by ceramic punches. The stamp is shift-driven up to a height reduction of 1 mm with velocities of 200, 20, 2 and 0.2 mm/s.

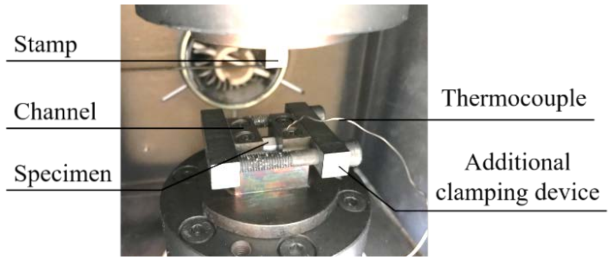

Fig. 3. Experimental setup.

3. Metallography

After test execution all specimens are metallographically evaluated. The boundary layer thickness is about 22µm due to the heat treatment during testing. For every specimen the length of each fragment and gap is measured, Fig. 4, to get an information about the deformation behaviour of the boundary layer.

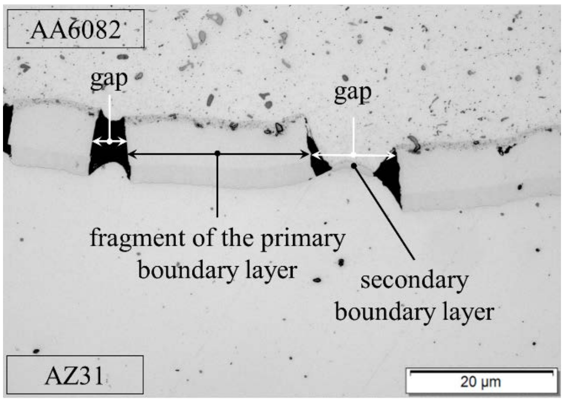

Fig. 4. Exemplary image of the boundary layer and gaps after channel upsetting.

4. Results

At first, the lengths of the fragments are summed up to a total length of the boundary layer which is shown in Fig. 5. Additionally, the total length has to be considered in relation to the initial state. To this end, the analytical length of the initial interface is used.

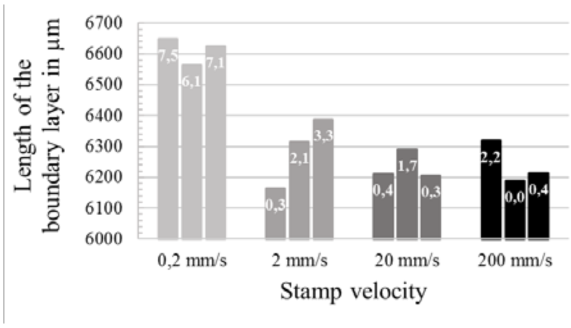

Fig. 5. Total interface length after channel upsetting of three specimens for every stamp velocity with the percentage extension of the interface in the bars.

Especially at a stamp velocity of 0.2 mm/s the interface shows a ductile behaviour with an extension of about 7%. At higher deformation rates the elongation at break is negligible.

In contrast, the length and amount of the gaps increase with the stamp velocity up to 20mm/s, Fig. 6. Then at higher deformation rates the percentage of the gaps on the total interface length stays equal. Only the number of gaps increases and accordingly the length of each gap decreases.

The evolution of the boundary layer fragments and the gaps at increasing stamp velocity shows a transition from ductile to brittle material behaviour. The boundary layer is then fully stiff and breaks into a large amount of small fragments. A limit of fracture toughness could not be reached in this study.

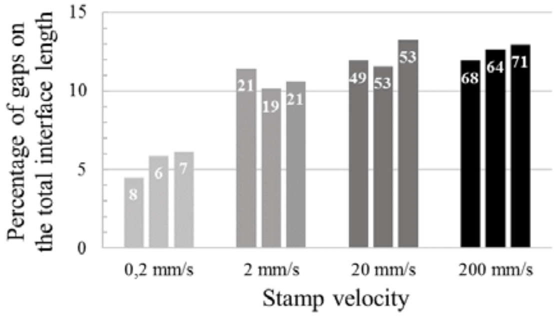

Fig. 6. Percentage of gaps on the total interface length after channel upsetting of three specimens for every stamp velocity with the amount of gaps in the bars.

However, the results indicate the possibility to deform the compound without fragmentation at low deformation rates.

5. Remarks

- Despite the fact that the boundary layer of the compound shows a brittle behavior the compounds can be formed without a destruction of the metallurgically bonded connection.
- The boundary layer fragmentation increases dramatically with the rate of deformation during the channel upsetting process.
- Further investigations including the dependency of the boundary layer thickness caused by different thermal treatments are planned .

Acknowledgements

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