Numerical/experimental investigation of the production of thin magnesium alloy components via superplastic forming

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Abstract. Magnesium (Mg) alloys are increasingly gaining attention from industry since they appear suitable for a variety of applications, spanning from medical, sports, and automotive to aerospace. Beside the possibility of reducing the fuel consumption and green-house gas emissions in transportation as well as in aeronautical applications due to the lightweighting, they are attractive also for biomedical prostheses being not only biocompatible and resorbable, but also very similar to the human bone in terms of mechanical characteristics. Due to the low formability at room temperature of these alloys, nowadays the possibility of producing complex shaped components is almost limited to the adoption of casting process. However, even through the high pressure die casting process, extremely thin parts cannot be easily produced while the sheet metal forming seems more suitable. But the adoption of elevated working temperature is necessary.

In the present study, SuperPlastic Forming (SPF) is proposed for producing a very thin Mg part having a hemispherical shape. In particular, the attention was focused on the AZ31B Mg alloy 1 mm thick which, as proven by literature, shows an emphasized superplastic behavior at 450°C. Both the numerical analysis of the process and trials have been conducted and detailed in this work. In order to correctly model the investigated alloy, free inflation tests at 450 °C were carried out setting different pressure levels in a range able to guarantee strain rate values between 10^{-4} and 10^{-1} sec^{-1}, in which both Grain Boundary Sliding (GBS) and Dislocation Climb (DC) creep can be observed. Both the strain and the microstructure were investigated by analyzing specimens formed by means of free inflation tests considered to better reproduce the strain condition of the industrial Gas Forming processes. In such a way parameters of a material model from literature, able to take into account the influences of both the grain coarsening and the stress values on the strain rate, were determined. Such a model was implemented in a bidimensional ABAQUS model of the forming process of the hemispherical component to predict the strain condition and the thickness distribution of the formed part when setting different pressure levels. Numerical results were finally compared to experimental ones.

Beside the effectiveness of the adopted modelling approach and the capability of the implemented model to simulate the SPF process, the possibility of efficiently producing the thin component by SPF was proven.

Keywords: Mg alloys; AZ31B; Material characterization; Free inflation tests; Superplasticity; Microstructure; Finite Element Analysis.