Study on the Influence of the Forming Velocity in Micro Impact Extrusion with Modular Dies

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Abstract

In this paper the influence of different forming velocities (stamp velocities) on the micro impact extrusion is investigated. The research is done on precision micro cavities which were formed into aluminium sheet material using micro impact extrusion. The dependency of the stamp velocity is characterized using geometric parameters, metallographic analysis, and surface roughness.

It was found that the grade of influence of forming velocity on characteristic parameters of the formed micro geometry depends on the sheet material thickness. For low thickness no influence was found, but for large thickness the velocity influences the achieved forming result.

1 Introduction

Within the Collaborative Research Centre SFB/Transregio 39 PT-PIESA "Production Technologies for Light Metal and Fiber Reinforced Composite Based Components with Integrated Piezoceramic Sensors and Actuators" of the German Research Foundation (DFG) the main topic is to develop mass production technologies to fabricate aluminium composite modules for sensor and actor applications.

For this purpose, piezo rods of $0.25 \times 0.25 \times 10\ mm^3$ size should be integrated into precision cavities which are formed in a sheet metal carrier. The production of these cavities is done by micro impact extrusion [1,2]. In macro forming the influence of the velocity is well understood [3]. But due to downscaling effects this behaviour is hardly transferable onto micro forming processes. Therefore the influence of the forming velocity on the cavity forming process is investigated in this study.

2 Design of Experiment

The investigations were performed using a 200 kN high precision forming press and a modular die which consist of ten long (16.8 × 0.3 mm²) and nine short (16.5 × 0.2 mm²) steel sheets. To reduce adhesion and friction between tool and workpiece, the sheets are coated with titanium nitride (TiN). The sheets are arranged alternately side by side and fixed by two clamping jaws (figure 1). During the micro extrusion process the material flows into the spaces between the long and the short die sheets and forms ten cavities with depths of 0.3 mm, widths of 0.3 mm, and a pitch between two cavities of 0.5 mm. In addition to that, the modular die forms four secondary spaces into the sheet for further functional elements (e. g. spaces for the piezo electrodes). The micro cavities are the functional parts of the formed geometry and need to fulfil high demands on precision and reproducibility. Therefore they are in the focus of this investigation.

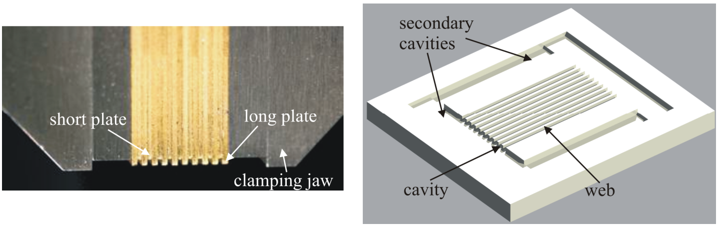

Figure 1: Modular die (left) and resulting geometry (right)

As workpiece 50 × 50 mm² aluminium sheets (AlMg4.5Mn0.4) with thicknesses of 0.8 and 1.5 mm were used. It is known from literature that for the used material the forming velocity has no influence on the achievable degree of deformation in cold forming processes in macroscopic dimensions [4].

The forming process was accomplished by applying constant stamp velocities between 0.5 and 1000 mm/min up to a maximum force of 195 kN. After the micro impact extrusion, which was done on five samples for each sheet thickness and stamp velocity, geometric parameters like cavity depth and width were measured optically using an optical measurement system (Nikon MM400). The degree of deformation φ was determined using equation (1), where s is the initial sheet thickness and d the cavity depth.

$$\varphi = \ln\left(\frac{s}{s-d}\right) \tag{1}$$

The mean forming velocity $\dot{\varphi}_m$ was calculated by

$$\dot{\varphi}_m = \frac{\varphi}{t} \tag{2}$$

Surface roughness was determined at the bottom of two cavities and on the top of two webs by using a laser microscope. For selected samples metallographic specimens were prepared.

3 Results and Discussion

The charts in figures 2 show the mean cavity depth in dependency on the stamp velocity for both sheet thicknesses. Mean cavity depths between 220 µm and 245 µm were achieved i. e. the maximum cavity depth of 300 µm were not reached. For the 0.8 mm sheets the stamp velocity has no influence on the cavity depths with an average of (226 ± 14) µm. In contrast to that, the cavity depths for s = 1.5 mm are affected by the stamp velocity. Depths between 225 µm (v = 1000 mm/min) to 245 µm (v = 0.5 mm/min) were machined. With the slowest stamp velocity the deepest cavities were formed. Furthermore it is visible that up to 250 mm/min the cavity depths in thick sheets are deeper than cavities into thin samples.

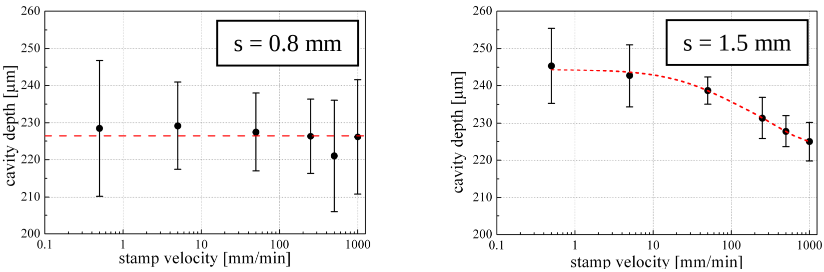

Figure 2: Mean cavity depth as function of stamp velocity

Out of the measured geometries and stamp velocities the degrees of deformation and the mean forming velocities were calculated. For 1.5 mm sheets a lower degree of deformation, φ = 0.16...0.18, is obtainable in comparison to φ = 0.32...0.34 for 0.8 mm sheets due to the different workpiece thicknesses. As known from the material's flow curve [4], a lower degree of deformation requires a lower yield stress due to strain hardening, which can give an explanation for achieving slightly deeper cavities at the 1.5 mm sheets. But this fact seems to have only a minor influence; otherwise the cavity depths would be constantly higher for thick sheets.

Figure 3a shows the cavity depth over the calculated mean forming velocity. For the 0.8 mm sheets $\dot{\varphi}_m$ is between 0.01 s^{-1} and 0.39 s^{-1} and for the 1.5 mm sheets the values are between 0.01 s^{-1} and 0.23 s^{-1}. An influence of the velocity onto the cavity depth is only visible for thick sheets. Figure 3b depicts the surface roughness on the webs and the cavity bottoms for s = 0.8 mm. The values are fluctuating but no trend is observable. For both sheet thicknesses the forming/stamp velocity has no influence on the roughness S_a.

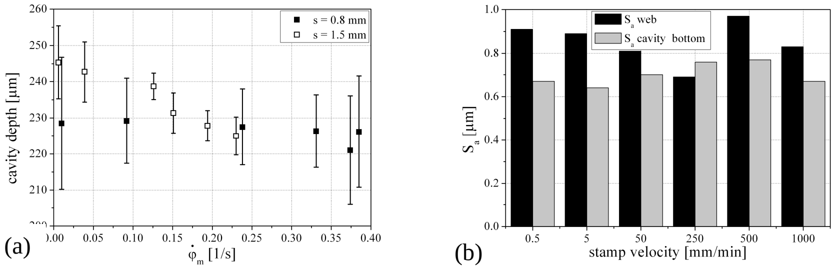

Figure 3: a) cavity depth as function of forming velocity, b) surface roughness for s = 0.8 mm

Figure 4 shows two metallographic images of 1.5 mm sheets after forming at stamp velocities of 0.5 (left) and 1000 mm/min (right).

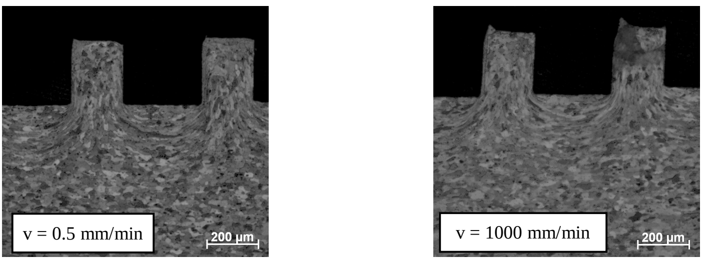

Figure 4: Metallographic samples of a 1.5 mm sheet

At fast velocities, the flanks of the cavity webs are tilted slightly which is inadmissible for the later function of the cavities. An elastic deformation of the modular die due to dynamic forces during the forming process is supposed to be the reason for this deviation from the geometry. A permanent deformation of the single die sheets after applying high stamp velocities was not detectable. A significant difference concerning the material flow was neither visible over different velocities nor in the two different initial sheet thicknesses.

4 Summary

The influence of stamp velocities from 0.5 to 1000 mm/min and thereof resulting different forming velocities onto the micro impact extrusion process was studied. Ten micro cavities of 300 µm width were formed into aluminium carrier sheets at a maximum force of 195 kN. For thin aluminium sheets with an initial thickness of 0.8 mm, the stamp/forming velocity has no impact onto geometric parameters like cavity depth. This result agrees with investigations done for macro sized forming processes [4]. In contrast to that, deeper cavity depths could be achieved by applying slow velocities onto thick carrier sheets with an initial sheet thickness of 1.5 mm. No velocity influence could be observed in the material flow and the surface roughness.
A deformation of the cavity walls is visible at samples formed at high forming velocities.

5 Acknowledgement

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