Micro Impact Extrusion of Precision Cavities with Modular Dies

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Abstract

Micro impact extrusion is investigated at Chemnitz University of Technology as a potential procedure for large area machining of micro cavities within the scope of the Collaborative Research Centre SFB/Transregio 39 PT-PIESA of the German Research Foundation. Applying impact extrusion, micro forming is done by material flow opposite to the effective direction of the force exerted by the tool. Therefore, no structured die plates are necessary, but high forming forces are required. In this study the influence of process parameters is investigated.

1 Introduction

On account of the progressive technical development in the areas of micro system and precision technologies, metallic small parts with structural dimensions of a few millimeters down to some micrometers are needed in high numbers of pieces. Therefore, development of suitable forming technologies is necessary to realize a competitive production of these miniaturized metallic components. Beside such procedures for the production of small parts, new techniques for defined microstructuring of big surfaces are requested increasingly. Starting from this point the Collaborative Research Centre SFB/TR 39 of the German Research Foundation "High-Volume Production-Compatible Production Technologies for Lightmetal and Fiber Composite-Based Components with Integrated Piezo Sensors and Actuators" (Großserienfähige Produktionstechnologien für leichtmetall- und faserverbundbasierte Komponenten mit integrierten Piezosensoren und -aktoren) works, among other topics, on the investigation of technologies for large area microstructuring of aluminium alloy thin sheets. Figure 1 shows schematically an example of a piezo-fiber metal module. To manufacture this module, cavities should be embossed on a metallic carrier material where piezo-elements can be inserted and joined by forming.

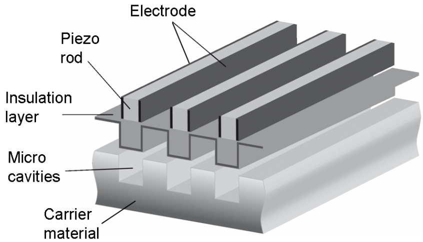
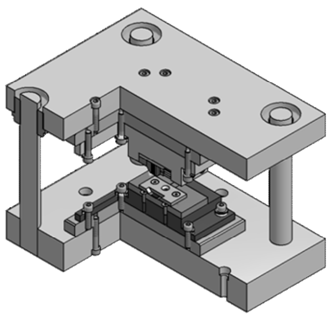


Figure 1: Schematic of a metal-based piezo module

The development of new technologies in micromachining is based on established laws for macro scale forming technology. In addition, different works on forming technologies for components with a size of some millimeters show that the know-how of conventional forming procedures cannot be transferred easily from the macro to the micro scale. In particular, frictional effects have a major influence on the forming process, especially for the increased surface-to-volume relation [1,2,3]. Not at least down-scaling effects of different process parameters like material, tool and machine are content of scientific investigations [4]. As a follow-up of these studies, investigations were performed at Chemnitz UT on material flow and the development of a suitable tool for micro impact extrusion of aluminium alloy sheets. Firstly, the application shown in Figure 1 was defined as model geometry consisting of micro cavities with a dimension of $10 \times 0.3 \times 0.3$ mm³ arranged on a flat surface. The pitch between neighbouring cavities is 0.5 mm with a resulting web width of 0.2 mm. With regard to potential applications in automotive industry two typical aluminium alloys (AlMg4.5Mn0.4 and ALSi1.2Mg0.4) were chosen as carrier material. The plate thickness was approximately 1 mm.

2 Development of modular dies

At first a tool system with modular die stamp was designed and realized. The die system shown on the left of Figure 2 is incorporated in a die set. Sheet specimens can be fixed by a blank holder on a substrate support. Warping of the test body is prevented by the clamping during the forming process. The modular forming die is mounted on the guide plate of the die set. The stamp structure can be configured on a modular basis and be adjusted for the respective experiment by an arrangement of form elements. The single elements were centered by a distance piece and braced by means of a wedge system. So several stamp parameters for example hardness, surface structure, surface roughness or coatings for one or more form elements can be varied by exchanging the elements without making a complete new stamp. Not at least all die elements can be disassembled after the experiments for an analysis of wear behavior. For the first experimental investigations on micro impact extrusion the reference structure of the stamp was realized by lined up hardened steel panels made of 1.2379 with different lengths (17.0 mm & 16.7 mm) and widths (0.3 mm & 0.2 mm).



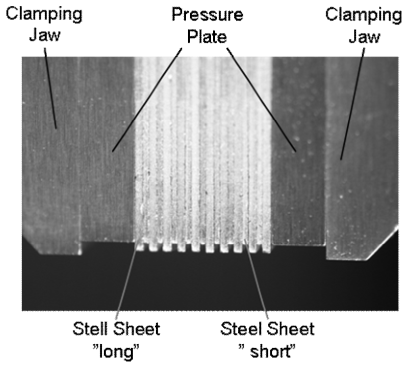


Figure 2: left: Scheme of the tool system, right: Photo of the modular die

Because of the known strong adhesion of aluminium in cold forming processes [5], the segments were coated with titanium nitride to decrease the friction and hence resulting reweldings. The negative trench web structure is generated by an alternating arrangement of long and short steel elements. A photo of the modular die is shown in Figure 2 right. The free length of the sheets is 300 µm. Clamping jaws on both sides of the stamp were used. These clamps were 200 µm longer than the structuring elements. The clamping jaws have two main functions. First function is an improvement of the clamping of the stamp elements. Second the lateral material flow should be reduced because the jaws are sinked into the material prior to the die.

3 Impact extrusion for plane microstructuring

After the successful die design, several experimental investigations on micro impact extrusion were performed. By help of forming 10 neighbouring cavities the suitability of the technology for a large area forming of microstructures had to be verified. Furthermore, several process parameters for the forming process and the mould design were determined.

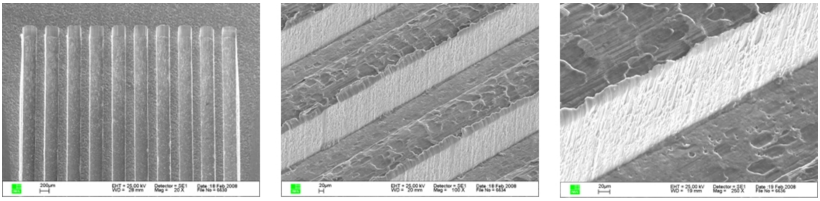


Figure 3: Micro cavities in aluminium sheet with a thickness of 0.8 mm, F = 90 kN

The experimental studies for impact extrusion were carried out in sheets of the aluminium magnesium alloy AlMg4.5Mn0.4 with a thickness of 0.8 mm. The process forces were determined experimentally as function of the metal thickness. Therefore, the force was varied in a range from 10 to 90 kN with a step width of 10 kN. In addition investigations for the reproducibility of the forming results were performed with the maximum forming force of 90 kN. Five replications were carried out on every metal thickness.

Figure 3 shows an example of the formed micro cavities. The SEM images show a consistent spreading of the structure over the whole formed area. The walls of the trenches are characterized by a side angle of approximate 90° and high degree of straightness. Looking at the top edges of the webs, a slight feathering burr formation was found. Furthermore, it was found that the top side of the webs has a surface curvature. Here the surface structure of the rolled and structured basic material is obvious. Consequently no contact between tool and work piece and therefore no entire forming out has taken place in this area. This shows that the forming force determined by the known rules of the macro forming technology is not dimensioned high enough. A possible reason for the increased force is friction between tool flank and work piece material.

4 Conclusions

In this study, a modular die for micro impact extrusion was investigated. The results applying this stamp indicate the promising potential of impact extrusion for plane forming of micro cavities. The investigations show that by means of impact extrusion a large area of reproducible structural features with a high degree of precision can be achieved.

5 Acknowledgment

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