

MICRO-PUNCHING EXPERIMENTS ON 20 μm THICK SHEET OF PURE ALUMINUM

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ABSTRACT

The paper presents some experimental researches performed by micromachining aluminium sheets of 99% pure aluminium with 20 μm thickness. The micro-punching experiments were performed on a MTS Alliance RT/50 testing machine. The used micro-punch has a height of about 90 μm and a nominal diameter of 400 μm . The tungsten carbide cylindrical micro-punch was machined by laser erosion with a Q-switched Nd:YAG laser. As a punch plate, a rubber support was used. During the experiments, the modified parameters were the punching speed and the rubber material, to obtain test diagrams (load versus crosshead displacement) and thus, to identify the most adequate material for the rubber plate. The optical microscope Leica DM-ILM was used for measuring and evaluating the micro-punched disk.

KEYWORDS: micro-punching, rubber die, aluminum, punching speed

1. INTRODUCTION

At the present time, as a response to the industry demands, a lot of metal forming processes were developed to obtain miniaturized components and devices for an extremely wide range of applications, from biomedicine to aerospace. Metal forming technology has the potential to become a technologically and economically feasible reality. A lot of micro-forming processes such as micro-forging, micro-coining, and micro-sheet metal forming have been studied [2, 3, 5]. In [3], a micro-punching system capable to obtain high quality holes of 25 μm is presented. Other researchers [2, 5] present contributions on micro-holes fabrications by various techniques. However, due to the difficulty of tools fabrication and high accuracy requirements of punching process, the mechanical micro-punching process is still in the research stage.

2. MICRO-PUNCHING PROCESS

The micro-punching experiments were performed for uniaxial uniaxial compression by a universal testing machine. The operation consisted in a blanking procedure where a 400 μm diameter flat faced cylindrical punch was driven through an aluminium sheet. The

specimen thickness was 20 μm and the height of the punch was of 90 μm , sufficient to penetrate the aluminium sheet. To avoid the problems related to the alignment between the punch and the die as well as the die fabrication, we did not use a conventional die-set structure. As die plate, we used some different rubber materials with different elastic properties. The aluminium sheet and the rubber plate were kept still by their own weight. No additional constraint or holder was necessary.

The micro-punch was realized by laser erosion with an industrial Q-switched diode pumped Nd:YAG laser (Fly 20 from LASIT) from a tungsten carbide sintered preform 2 mm in diameter. Working in the focalization conditions, a single material layer was ablated as a circular zone from the preform flat surface. The obtained punch height was equal to the laser beam diameter.

A scheme of the shear punch test is shown in figure 1. The load cell of the testing machine measured the force during the process. The crosshead displacement was measured by a linear travel device, placed on the crosshead of the machine. During the experiment, the punch was moved at a constant rate. The adopted values for the speed were 0.05 mm/min, 0.1 and 1 mm/min. As the load was applied to the samples in a downward

direction, load and crosshead displacement data were recorded automatically on a MTS Alliance RT/50 testing machine. At last, the punched parts were observed and measured by the using of the optical microscope Leica DM-ILM.

3. THEORETICALLY CONSIDERATIONS

The micro-punching process was performed by the using rubber plate and a rigid punch. During the operation, the punch exerted a pressure on the blank and will thereby deforming and the rubber plate. At the end of the punch movement, the aluminum sheet was sheared. The rubber-die punching can be used to obtain different diameters or shapes. The process is relatively cheap and flexible and it could be applied in particular for small product series, in particular.

The punch penetration depth in the workpiece during shearing depends on the workpiece material and thickness, the rubber plasticity, the punch diameter, the quality of the punch sharpened edges, the punching speed etc. The punch was designed to have three zones; the first one was 400 μm in diameter and 0.9 mm in height. The second zone was 2 mm in diameter, the third zone, 10 mm in diameter, was used for clamping on the crosshead of the testing machine by means of the coupling nut. The obtained parts consisted in circular ring with an external diameter of about 2 mm and a pierced disk 400 μm in diameter, corresponding to the first zone of the punch. During the experiments, a drawing phenomenon occurs at both the levels where the shearing is produced, due to the rubber elasticity and its deformation.

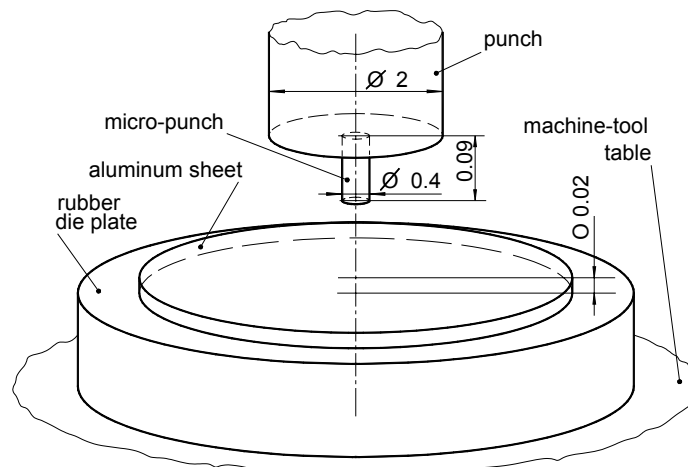


Fig. 1. Scheme of the micro-punching experimental set-up

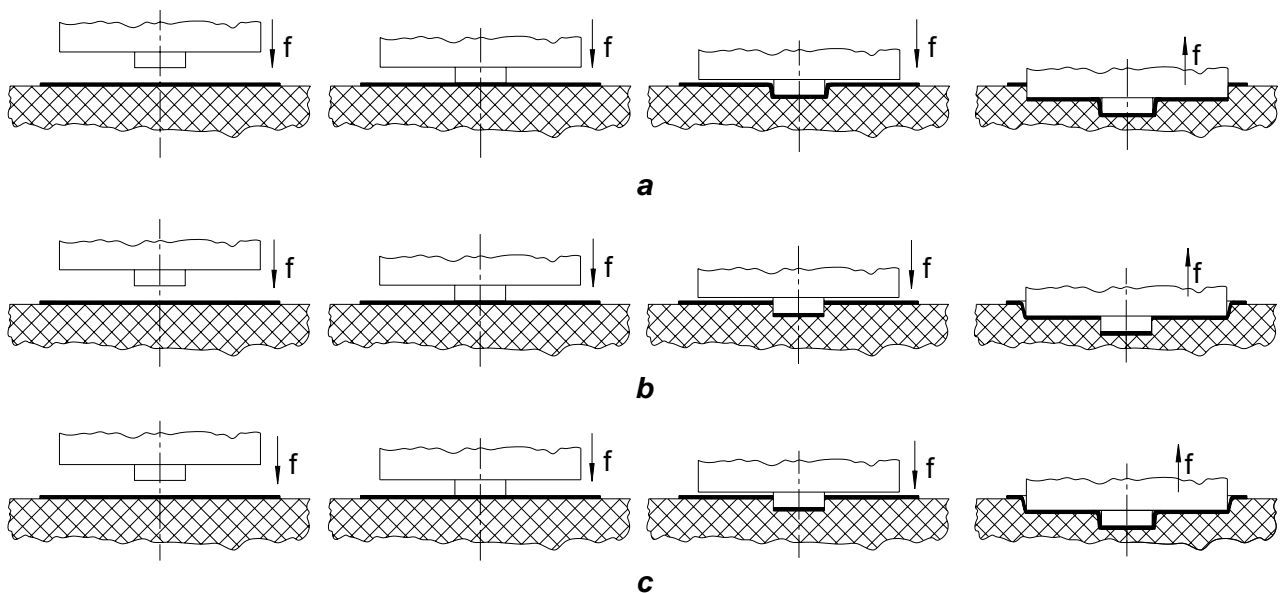


Fig. 2. Different experimental possibilities for rubber die micro-punching

In this particular process, the necessary force for shearing the workpiece is bigger than the process involving the regular punch and the die process. The rubber used for this process should have the following recommended characteristics [6]: the ultimate strength of 0,30...0,60 daN/mm²; the elongation per unit length of 300...400%, the Shore hardness of 80, the permanent elongation of 15...20%, the compression under the load of 100 daN/mm² of 40...50%. The necessary force for shearing/punching with a rubber-die can be determined [1, 6] by the using of the relation:

$$F = Ap \quad (1)$$

where - A [mm²] is the total surface of the machined hole and p [daN/mm²] is the pressure applied on the punch, calculated by the following formula [6]:

$$p = \frac{4s\tau_s}{D} \quad (2)$$

where - s [mm] is the workpiece thickness; D [mm] - the hole diameter; τ_s [daN/mm²] - the shear strength of the workpiece material (in our case, $\tau_s = 22$ daN/mm² for annealed aluminum and $\tau_s = 38$ daN/mm² for cold hardened aluminum). By using $\tau_s = 220$ N/mm² for the admissible shear strength of aluminum [1], calculating the necessary force for shearing in the case of the hole having the diameter $D = 400$ μ m and, respectively, the force for shearing in the case of the hole having the diameter $D = 2000$ μ m, we obtain $F_{400} = 5.52$ N, and $F_{2000} = 138$ N.

From experimental point of view, using different supports, we observed three different specific situation to the shearing process (fig. 2, a, b, c).

The first one supposes the separation of the big diameter and afterward no shearing for the piece. A second possibility is the obtaining of the small piece but no shear for the external diameter.

The third possibility is takes into consideration no shear but drawing to both diameters.

4. RESULTS AND DISCUSSION

After tool fabrication, punching experiments was carried out. Five different rubber materials were used as die plate necessary for micro-punching of aluminium sheets having a thickness of 20 μ m. The process

was conducted at the punch speed of 0.05 mm/min, 0.1 and 1 mm/min and no lubrication was used. The punched parts were examined in terms of surface quality and results were analyzed in connection with the theoretical shearing necessary force.

In figure 3, the both contours obtained in the punching process could be observed: the contour corresponding to the disk with 400 μ m and the external contour of the ring part having a diameter of 2 mm. On the external punched part circular concentric marks, corresponding to the scansions performed during the laser machining of the micro-punch, are visible. It is observed also a radial line that joins the circular laser paths.

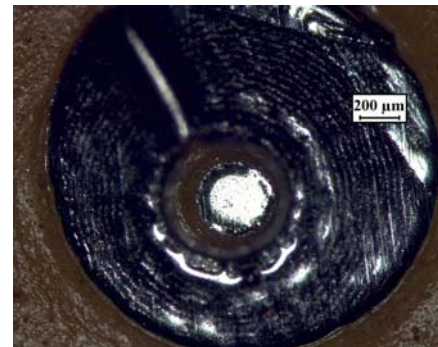


Fig. 3. Micro-punched part

The micro-punched part is of about 400 μ m in diameter and no significant distortions are present. A relatively small burr with an irregular shape is present, because of the punch melted zones. No distortions are visible, except the plastically shear area produced by the punch during machining.

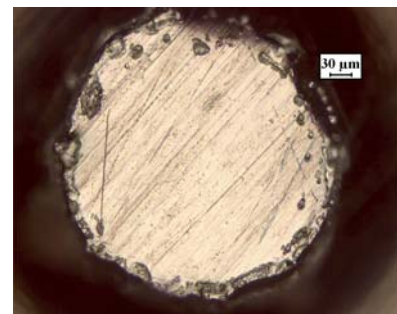


Fig. 4. Micro-punched interior contour

This occurrence demonstrates that the aluminum sheet perfectly matches the micro-punch during shearing. In figure 5 the irregular contour of the disk is shown.

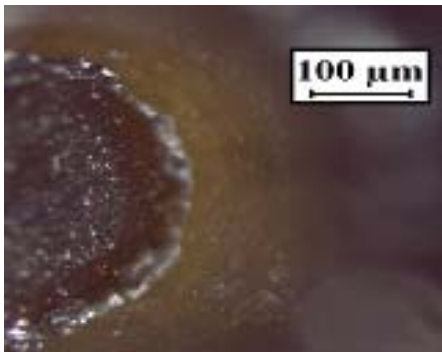


Fig. 5. Micro-punched part

The diagram in figure 6 was obtained for the best rubber material in terms of springback. This material property allows to easily remove the specimen after punching. By examining the diagram presented in figures 6, we can notice that the curves present a variation in the slope approximatively at 2N and a peak load approximatively at 14N, we suppose that these load values correspond respectively to the shearing at 400 µm and 2mm diameter. The real forces corresponding to these moments are $F_{r\ 400} \approx 1.5...2\text{ N}$ and $F_{r\ 2000} \approx 12...16\text{ N}$. The differences existing between the values of the force calculated by the using of the theoretical relations and the values experimentally determined could be justified by the fact that the theoretical relations do not take into considerations the real properties of the workpiece material (the real behavior of the material) and the real experimental conditions.

5. CONCLUSION

In this paper, the micro-punching performed with rubber die was studied. The process was carried out by using the punching speeds of 0.1, 0.5 and 1 mm/min.

Different rubber materials were used for die plate to punch aluminum sheets 20 µm in thickness. In the future, we have the intention to more detailed study the microprocess; other interesting direction could be to try the simultaneous punching process of many aluminum sheets.

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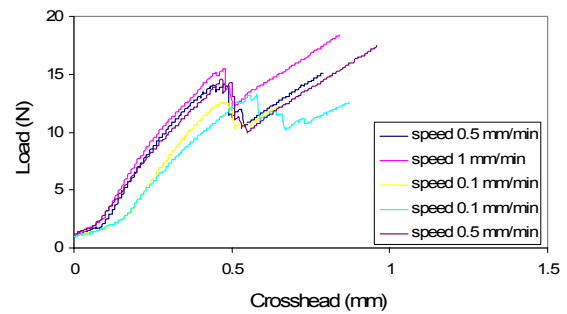


Fig. 6. Force evolution during the punching process

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