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INCREASING THE DEEP DRAWABILITY OF Al-1050 ALUMINUM SHEET USING MULTI-POINT BLANK HOLDER

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Aluminum alloys have been widely used in the fields of automobile and aerospace industries. Due to their bad cold-formability in deep drawing, a lot of forming methods have been implemented to increase the drawing height and the limiting drawing rate (LDR). The conventional deep drawing process is limited to a certain limit drawing ratio beyond which failure will ensue. The purpose of this experimental study is to examine the possibilities of increasing this limitation using the multi-point blank holder. The results from the experiments showed that the multi-point blank holder is effective way to promote deep drawability of Al-1050 sheet.

Key words: *aluminum sheet, deep drawing; multi-point blank holder*

Povećanje sposobnosti dubokog izvlačenja Al-1050 aluminjskog lima primjenom višetočkastog pritiskivača. Aluminijske se legure mnogo koriste u području automobilske i zrakoplovne industrije. Zbog njihove slabe deformabilnosti u hladnom stanju tijekom dubokog izvlačenja brojne su metode implementirane za povećanje izvlačenja i granične brzine izvlačenja (LDR). Uobičajeni postupak dubokog izvlačenja ograničen je do određene granice iznad koje dolazi do oštećenja. Cilj je ovog eksperimentalnog rada da se ispitaju mogućnosti za porast te granice uporabom višetočkastog pritiskivača. Eksperimentalni su rezultati pokazali da je višetočkasti pritiskivač efikasan način za povećanje sposobnosti dubokog izvlačenja Al-1050 lima.

Ključne riječi: *aluminijski lim, duboko izvlačenje, višetočkasti pritiskivač*

INTRODUCTION

The deep drawing is a process for shaping flat sheets into cup-shaped articles without failure or excessive localized thinning. The design and control of a deep drawing process depends not only on the material, but also on the condition of the tool material interface, the mechanics of plastic deformation, the equipment used, and the control of metal flow. The equipment and tooling parameters that affect the success or failure of a deep drawing operation are the punch, die radii, die clearance, the press speed, the lubrication, the type of restraint to metal flow such as blank holding force (BHF) [1], blank holder gap (BHG), and draw bead. All of these three types of restraints create restraining force by friction between the strip and the tooling. In this work, the effect of multi-point blank holder on the LDR of Al-1050 sheets was investigated using (BHG) defined as the fixed distance between the blank holder and the die surface in the stamping process by Weili et al. [2] to promote the deep drawability of aluminum sheets.

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To establish the geometry of a part, it is essential to know the limit to which the part material can be formed without reaching failure. This forming limit depends, in addition to the shape change and process conditions, on the ability of a material to deform without failure. The limit drawing ratio (LDR) is commonly used to provide a measure of the drawability of sheet metal.

Many studies have been done to increase the LDR. A new blank holder system with degressive gas springs developed by Gunnarsson et al. [3] to large process window between fracture and wrinkling in axi-symmetric deep drawing and to increase the LDR. Moon Y. H. et al. [1] showed that the tool temperature control is very effective way to promote deep drawability of Al-1050. Sato et al. [4] investigated the effect of the multi-axial loading path on limiting drawing rate at a square cup deep drawing of thick plate using a punch and four-side tools and showed that appropriate multi-axial loading paths provide a considerably larger LDR improving about 55 % than the conventional method. Jimma et. al. [5] applied ultrasonic vibration to the die and blank holder in the radial direction for SPCC (cold rolled steel), SPCE (cold rolled steel for deep drawing), and SUS304 (304 stainless steel) and increased the

LDR. Manabe et al. [6] proposed a new control system using a combination punch speed and blank holder using fuzzy control for the deep drawing process to improve the productivity and formability of sheet metal having strain rate sensitivity.

In this study, the effect of multi-point blank holder on deep drawing of Al-1050 aluminum square cup was investigated experimentally and the experimental results were presented.

EXPERIMENTAL WORK

Table 1. **Mechanical properties of Al-1050 sheet**
Tablica 1. **Mehanička svojstva Al-1050 lima**

Specimen angle to rolling direction	Tensile properties				
	Yield strength / MPa	Tensile strength / MPa	Uniform strain		
0°	114,93	125,91	0,020		
45°	123,26	132,97	0,019		
90°	126,99	135,72	0,017		
Formability parameters					
	k	n	r	r_m	Δr
0°	16,8	0,065	0,67		
45°	17,5	0,060	0,45	0,58	0,25
90°	176	0,056	0,73		

Commercially available Al-1050 aluminum sheet with a thickness of 1,0 mm is used for the blank material. The mechanical properties of the material used in this investigation are shown in Table 1. [1].

Multi-point blank holder (MPBH), basically, consists of normal blank holder (NBH) under which balls have been placed most closely packed between inner and outer spacer rings. The photograph and dimensions of this blank holder are shown in Figures 1. and 2., respectively. The diameter of the balls and the thickness of the spacer rings are 2,5 mm and 2 mm respectively. The span of rings is calculated considering the most closely packed of balls.

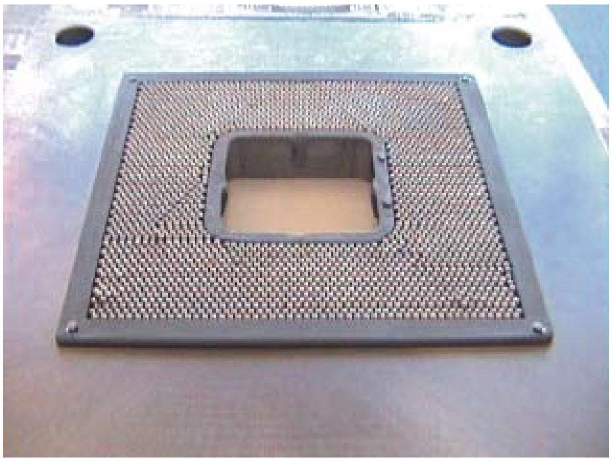

Figure 1. **Photograph of multi-point blank holder**
Slika 1. **Fotografija višetočkastog pritiskivača**

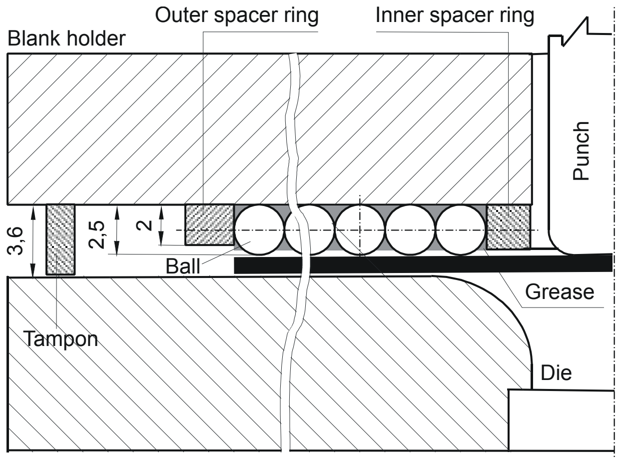

Figure 2. **Dimensions and tooling geometry of multi-point blank holder**
Slika 2. **Dimenzije i polazna geometrija višetočkastog pritiskivača**

When the balls are placed, some of disorder gaps comprised in the corner regions as shown in Figure 3.

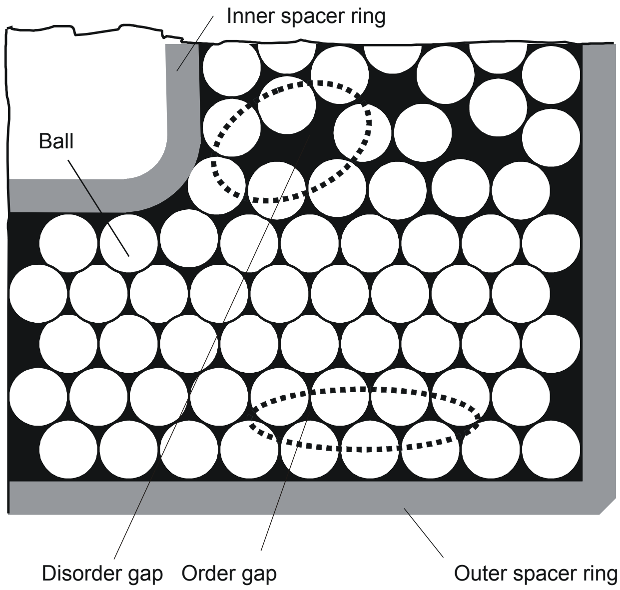

Figure 3. **Disorder and order gaps comprised among the balls**
Slika 3. **Nesređene i sređene praznine zbijene između kuglica**

In order to place the balls, firstly, the lower surface of the blank holder was covered with grease in approximately 1 mm thickness. Later, the balls were placed into grease with most closely packed system one by one by hand and the gaps among balls and rings were filled up with grease completely. In this study, a hydraulic press with a maximum load capacity of 80 ton and maximum punch speed of 6,95 mm/s is used. Figure 4. schematically shows punch and dies set used in this work.

In the present study, circular blanks having the same thickness of 1 mm, but with different diameters ranging from 100 to 120 mm in an increment of 1 mm, were studied. The sheet was cut without considering the rolling direction for each size of blank. Drawing speeds of 6,95 mm/s was used in this study. The blank holder gap, defined as the distance between the blank holder and die surface as shown in Figure 4., is one of the most important process variables controlling the sheet forming process for a given tool design. In

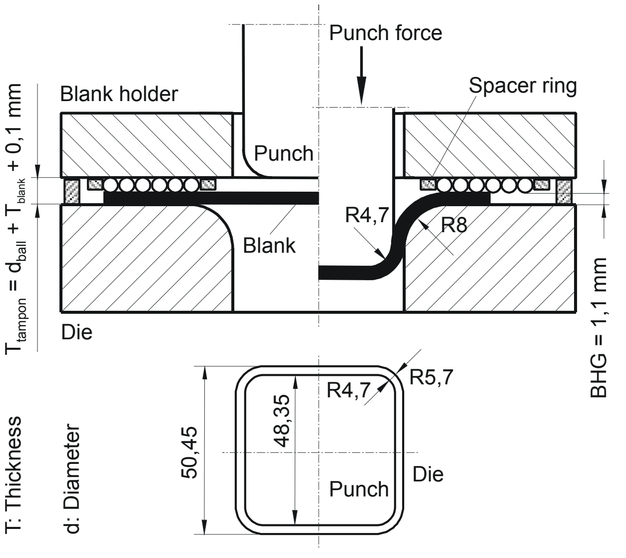

Figure 4. **Schematic illustration drawing of punch and die set**
Slika 4. **Shemtaski prikaz rezanja i probijanja (štancanja)**

this study the BHG was chosen 1,1 mm which is 110 % of the initial material thickness. Mobile oil 30 was used as a lubricant in the drawing operations. Upper surface and cavity of the die, and lower and upper surfaces of the blanks were lubricated. The oil was brushed a little on to the upper surface of the blank, which is in contact with the balls.

RESULTS AND DISCUSSION

In deep drawing, the use of multi-point blank holder is expected to be very effective in achieving better drawability and higher drawing height.

Figures 5. and 6. show the effect of multi-point blank holder on the LDR and cup height of Al-1050. To calculate LDR, maximum blank diameter below which the blanks will be drawn successfully in the cup wall is determined.

For the deep drawing of Al-1050, LDR was increased from 2,33 to 2,39 by the multi-point blank holder. Due to limitation of the blank size, LDR more than 2,39 could not be obtained. Moon et. al. [1], has increased the LDR from 1,862 (punch temperature: 25 °C, die temperature: 25 °C) to 2,096 (punch temperature: –10 °C, die temperature: 200 °C) using the same material (Al-1050) and heating/cooling punch and die for his tooling geometry. Bolt et. al. [7], has increased the 130 × 210 mm rectangular part height from 80 mm to 100 mm (at room temperature 80 mm product height blank, and at 175 °C with a 100 mm product height blank) using Al-1050H14 and heating the die. Figure 5.

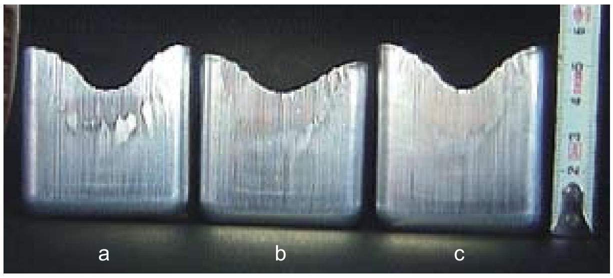

Figure 5. **Comparison of cup heights and limiting drawing rates (LDR): a) With normal blank holder, blank diameter of 113 mm, LDR 2,33, b) with multi-point blank holder, blank diameter of 113 mm, LDR 2,33, c) with multi-point blank holder, blank diameter of 116 mm, LDR 2,39**
Slika 5. **Usporedba visina čaše i graničnih brzina izvlačenja (LDR): a) s normalnim pritiskivačem promjera 113 mm i LDR-a od 2,33 b) s višetočkastim pritiskivačem promjera 113 mm i LDR-a od 2,33 c) s višetočkastim pritiskivačem promjera 116 mm i LDR-a od 2,39**

shows photographs of deep drawn cups at given process conditions. This figure indicates that for normal blank holding system (without multi-point/ball), the drawing height and LDR is smaller than that obtained from with multi-point blank holder system. Figure 6. shows the comparison of cup heights obtained by two methods (with multi-point blank holder and normal blank holder). The cup height with multi-point blank holder is improved by 3,27 mm more than the normal blank holder one. The improvement ratio of cup height is 6,13 %. This discrepancy

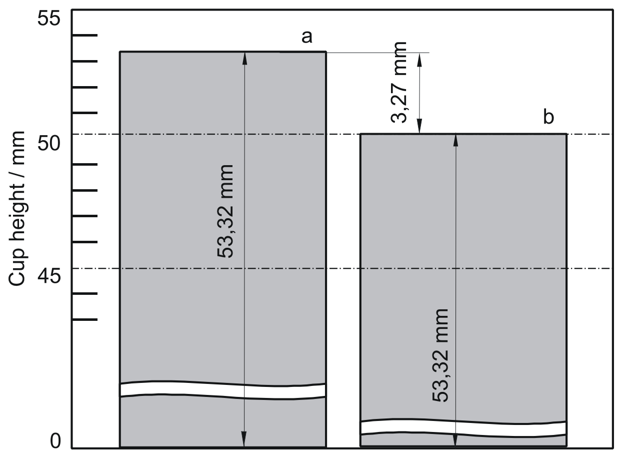

Figure 6. **Comparison of cup heights (mean value of four corners, including earring): a) with multi-point blank holder, blank diameter of 116 mm, b) with normal blank holder, blank diameter of 113 mm**
Slika 6. **Usporedba visine čaše (srednja vrijednost četiri kuta): a) s višetočkastim pritiskivačempromjera 116 mm b) s normalnim pritiskivačem promjera 113 mm**

in the drawing height explain that the normal blank holder makes the material flow difficult for fracture although the fracture may depend on other process variables such as die and punch radius and blank holding gap, and so on.

Figure 7. shows fracture types obtained from experiments with normal blank holder and multi-point blank holder. Only one type fracture occurs in all of the experiments, the middle fracture. This type of fracture happens almost the sheet drawing forces produced by the sheet deformation and the friction reaches the peak punch force. During drawing process, for normal blank holder after the blank diameter of 113 mm and for multi- point blank holder after the blank diameter of 116 mm, axial stresses of the cup walls exceed the deformation resistance of the sheet and therefore fracture occurs in the corners and side walls of the cup as shown in Figure 7.

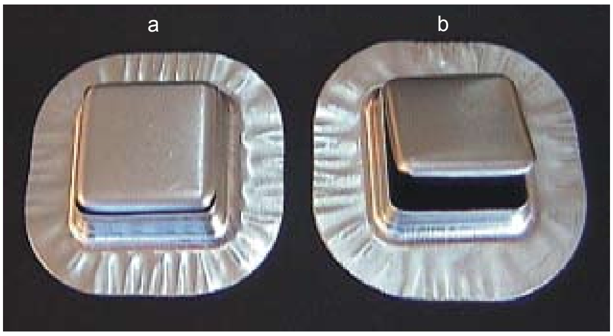

Figure 7. **Fracture types obtained from experiments: a) with normal blank holder, blank diameter of 114 mm, b) with multi-point blank holder, blank diameter of 117 mm**
Slika 7. **Oblici prijeloma dobiveni eksperimentima: a) s normalnim pritiskivačem promjera 114 mm b) s višetočkastim pritiskivačem promjera 117 mm**

Figure 8. displays the relations between the forming load and the drawn depth obtained from the experimental work. The multi-point blank holder does not alter the punch load and its maximum value so significantly. For the blank diameter of 113 mm with normal and multi- point blank holder, the maximum punch load is nearly the same. For the blank diameter of 116 mm with multi-point blank holder, the maximum punch load slightly increases due to large LDR.

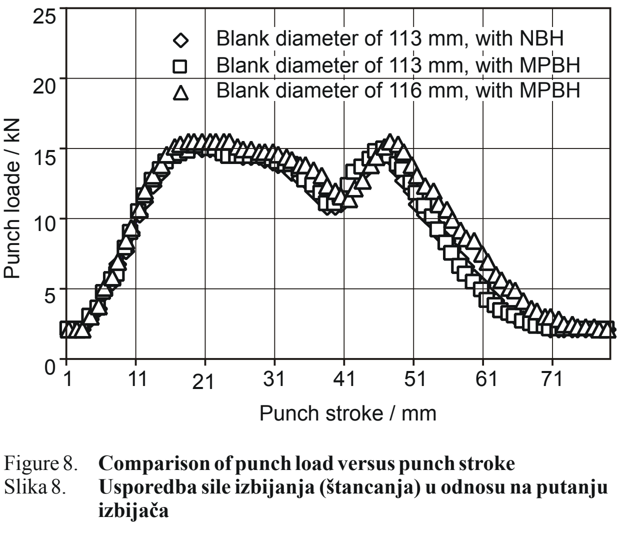

Figure 8. **Comparison of punch load versus punch stroke**
Slika 8. **Usporedba sile izbijanja (štancanja) u odnosu na putanju izbijača**

The thickness distributions of cross-sectioned cup is shown in Figures 9. and 10. To cut the drawn cup along the *x* and *y* axis's, each aluminium cup was placed in a wooden container concentrically and container was filled up with liquid plaster After drying; the container, plaster and aluminium cups were cut all together on the milling machine. Thus, the measuring lines and form of the cups were protected from deformation and being ragged. Then, a micrometer with a cone-point attachment was used to measure the thickness of the workpieces. Figure 9. presents a comparison of the sheet-thickness distribution for the *x* axis and Figure 10. presents a comparison of the sheet thickness distribution for the *y* axis. The distributions of the thickness involve three parts: A, B and C. The region A represents the bottom of the cup, the region B represents the arc portion of the cup and the region C is the straight-wall portion of the cup. These results indicate that the first thinning occurred in region B for all of the cups. This is attributed to the maximum tensile force and stress concentration that occurred at the arc point. The second thinning is observed in the starting of the region C. This is still due to the tensile force occurring in the straight cup wall and round shaped blank that causes ear and increases tensile force. The numerical thickness for region A under the punch head remains unchanged for all of the cups.

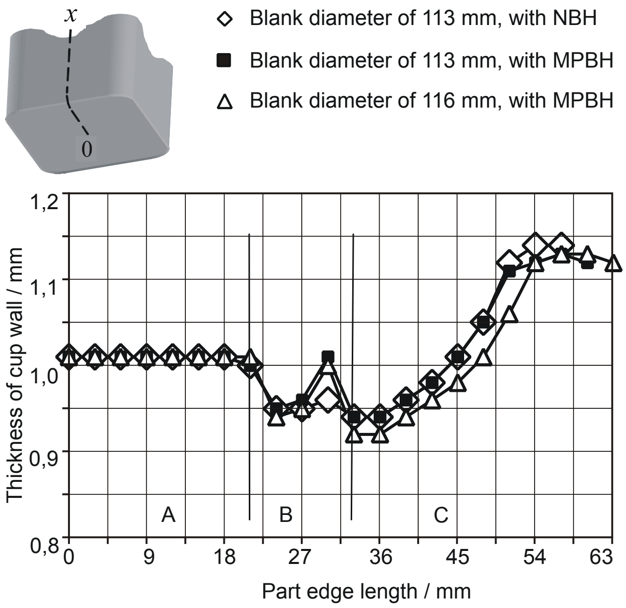

Figure 9. **Comparison of the thickness of sheet distributions along the *x* axis**
Slika 9. **Usporedba raspodjele debljine lima duž *x* osi**

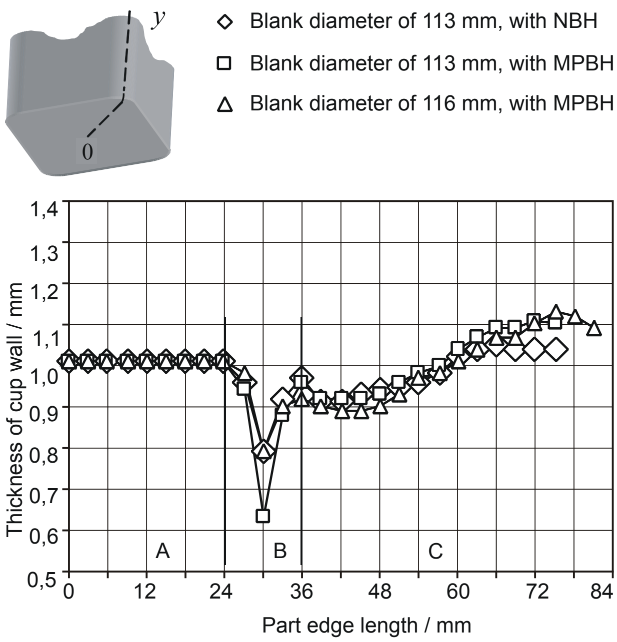

Figure 10. **Comparison of the thickness of sheet distributions along the *y* axis**
Slika 10. **Usporedba raspodjele debljine lima duž *y* osi**

Generally, there is no significantly difference in thickness distributions among the cups drawn with normal blank holder and multi-point blank holder.

CONCLUSIONS

In this study, the square cup drawing of aluminum alloy Al-1050 sheets was studied using multi-point blank holder experimentally. The experimental results showed that multi-point blank holder facilitates direction and flow of the metal. The higher LDR and cup height are achieved compared to normal blank holder when the multi-point blank holder is used. Surface quality is nearly the same compared to normal blank holding system, however, slightly ball-scratch was found inner surface of the side wall of the cup.

In this method, though the drawing height and LDR are increased, however, it is not very practical because of placing difficulties of the balls under the blank holder with grease. This method can be used practically placing of the balls to the blank holder tightly with another method that will be investigated, or making the blank holder surface multi-point with different methods without placing balls. Using a multi-point blank holder may not be the best method to obtain the highest LDR, but it can increase the LDR substantially and can be used for special purposes.

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