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Finite Element Analysis of Angular Deep Drawing Process without Blank Holder

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Abstract-The deep drawing method is widely used in the metal industry. With this method, metal sheets are formed in the desired form. In this study, a finite element analysis of the deep drawing process of DC02 sheet was made using an angular die. In the study, 15 different die radii were used. 10° die angle was used in all experiments. A blank holder was not used in this study. The effects of different die radii on the forming process were investigated. As a result of the study, it was determined that the most suitable die radius in terms of both equivalent plastic strains (PEEQ) and Mises stress was 8 mm. It was observed that the largest stresses occurred just above the cup radius, and the plastic strain increased as it moved towards mouth region of the cup.

Keywords-angular deep drawing, deep drawing, finite element analysis, Abaqus

I. INTRODUCTION

A deep drawing method is widely used in the production of sheet metal parts. In this method, flat sheets are formed using a special mold. The mold consists of three basic elements: die, punch, blank holder. Punch forms the sheet by pushing it into the gap on the die.

The blank holder prevents the formation of wrinkling on the sheet by applying force on the sheet. If the blank holder force is more than necessary, tears occur in the sheet. If it is less than necessary, wrinkling occurs on the sheet. It is very important to apply this force well.

Production and use of blank holder are costly. Instead, there are molds where the blank holder is not used [1]. These molds can be used especially for shaping thick sheets [2].

Another application that facilitates deep drawing is the use of angular die. Thinning in wall thickness may be less when using an angle die [3-5]. Savas et al. formed the 1050 aluminum alloy sheet using an angular die. They stated that when using a 12.5° angle, better results can be obtained [6].

Özek and Taşdemir performed the warm deep drawing process of AA 5754-O alloy with angular dies. In the study, they used dies with angles of 0 ~ 15°. They used three different temperatures. They determined that the increase of temperature and blank holder force together decreased the wall thickness of the sheet [7]. Özek and Taşdemir stated in another study that 5^o- 10^o die angle is ideal [8].

Reddy et al. Also shaped 304 stainless steel and brass sheets with an angle molding method. They warmed the sheets to make it easier to shape. They achieved a more uniform thickness distribution when the sheet was heated [9].

Dhaiban et al. performed finite element analysis using ANSYS, the deep drawing method without blank holder. With this method, they determined that the elliptical part of the limiting drawing ratio (LDR) was 2.28 [10].

In this study, a finite element analysis of the deep drawing process of DC02 sheet was made using an angular die. Blank holder was not used in the study. The effects of different die radii on the forming process were investigated. Finite element analysis was done with the ABAQUS program.

II. FINITE ELEMENT SIMULATION

In this study, a finite element analysis of the angular deep drawing process of a 1 mm thick DC02 sheet was made. The axial symmetrical part was used in the analysis. The piece's outer diameter is 42 mm and the height is 33 mm (Fig. 1). In all analyzes, it was kept constant at 10^o die angle.

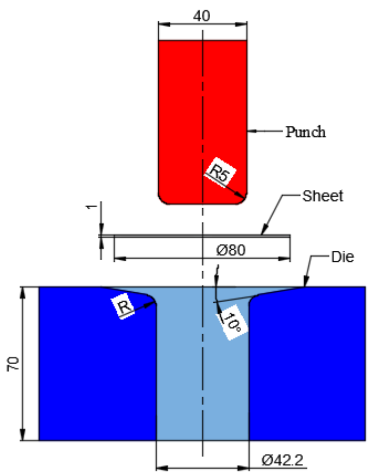

Fig. 1. Mold set used in analysis (dimensions are in millimeters)

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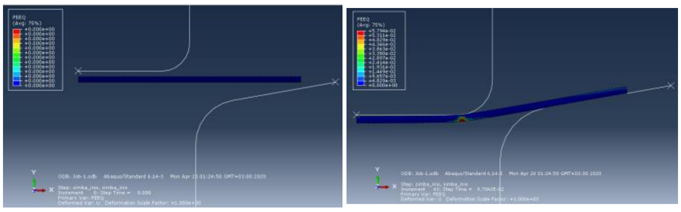
The sheet was partitioned into 5 different parts in the direction of thickness. Thus, calculation accuracy has been increased. Punch and die were defined as analytic rigid. Sheet was defined as deformable. The sheet was meshed 4-node bilinear axisymmetric quadrilateral (CAX4R) element (Fig. 2).



A **B**

Fig. 2. View from finite element analysis. A: Developed model. B: Start of forming

Die radius is defined by increasing two millimeters starting from 2 mm up to 30 mm. Thus, 15 different analyzes were made. In the finite element analysis, 3 different steps were defined.

a) Forming step

b) Punch removal step

c) Die removal step

During the forming step, the punch went down and formed the sheet (Fig. 3). In the step of punch removal step, the punch went up and left the piece. In the step die removal step, the formed piece was separated from the die. Thus, spring back/residual stress on the part produced, etc., effects were also taken into account.

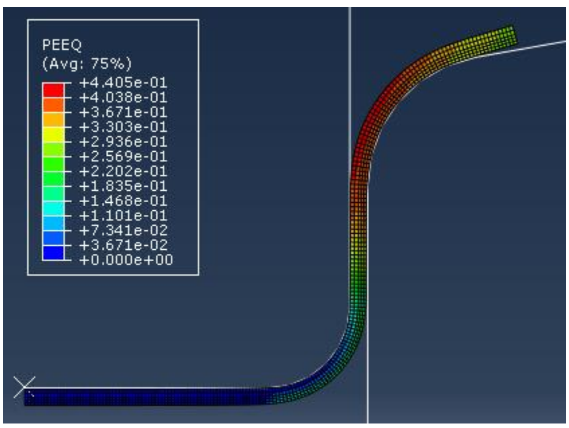


Fig. 3. A view of forming step.

III. RESULTS

A total of 15 different analyzes were performed using different radii. The equivalent plastic strains (PEEQ) values formed in the parts determined as a result of the analyzes are given in Fig. 4. According to the figure, the largest equivalent plastic strain was occurred in the experiment using 2 mm die radius. In Fig. 5. strain analysis results for 2, 8 and 30 mm mold radii and in Fig. 6., strain results occurred along the wall of the cups obtained as a result of the analysis are given. When the figures are examined, it is seen in all analyzes that the largest equivalent plastic strain occurs in the mouth regions of the parts. This shows that the greatest shape change occurs in the mouthparts of the cups. The biggest equivalent plastic strain is formed in the position, which is formed with 2 mm die radius; due to the small die radius, the flow of the material into the die clearance is very difficult. There was also some increase in the equivalent plastic strain as the friction surface increased as the mold radius increased. As a result of the analyzes, the lowest equivalent plastic strain was obtained in the 8 mm die radius.

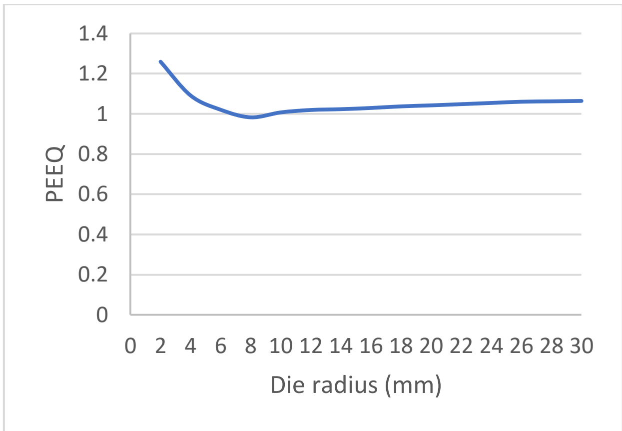
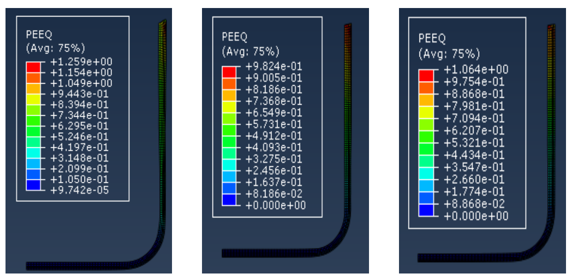


Fig. 4. Equivalent plastic strain results.



R=2 mm **R=8 mm** **R=30 mm**

Fig. 5. Equivalent plastic strain values obtained after forming.

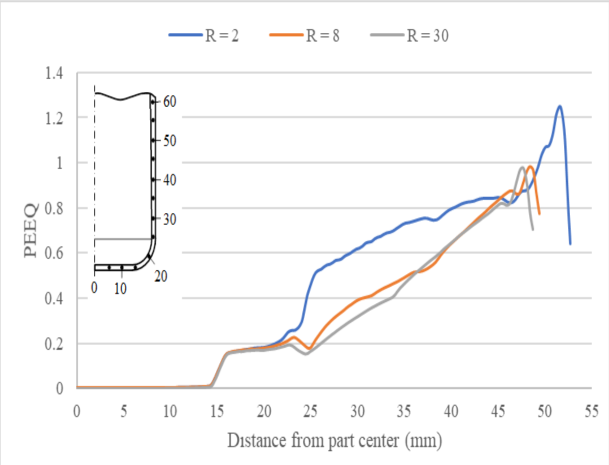


Fig. 6. PEEQ distributions

Misses stress values occurred in the parts as a result of the analyzes are given in Fig. 7. When Fig. 7. is examined, it is seen that the maximum stress values are close to each other for all parts. However, the biggest stress was obtained in the 2 mm die radius. In Fig. 8., stress analysis results for 2, 8 and 30 mm die radii are given, while in Fig. 9., the stress results formed along the wall of the cups obtained as a result of the analysis are given. When the analyzes are examined, it is seen that the greatest stress occurs in all shapes in the area just above the cup corner radius. However, it was happened a little above in the 2 mm die radius. This situation can be explained by the thinning in the cups after the material flow becomes difficult.

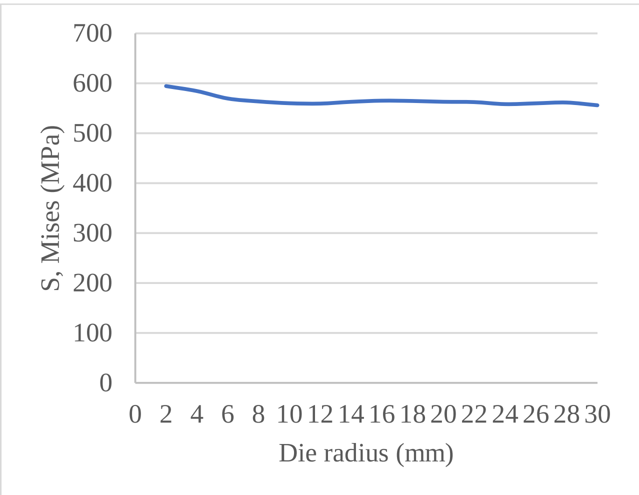
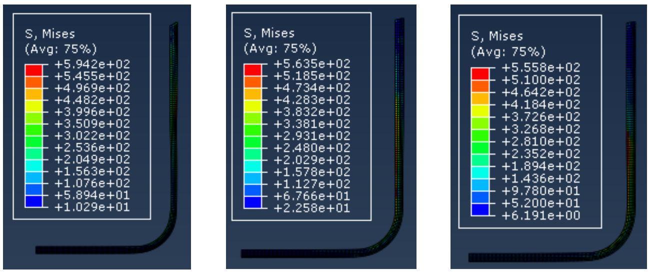


Fig. 7. Mises stress.



R=2 mm **R=8 mm** **R=30 mm**

Fig. 8. Mises stresses in the piece after forming

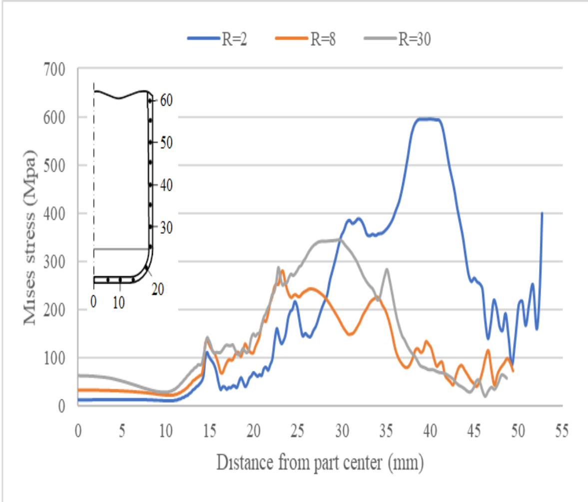


Fig. 9. Stress distributions

IV. Conclusion

In this study, forming analysis of the DC02 sheet was made using angular deep drawing method without a blank holder. The effects of 15 different die radii on PEEQ and stress were examined. As a result of the study, it was determined that the optimum die radius was 8 mm. It was determined that sheet flow was difficult in larger die radii such as 2 mm, 4 mm and larger PEEQ occurred. It was determined that the die radius has no significant effect on the material flow at 10 mm and above values. The plastic strain distribution increases as moved towards the mouth region of the cup. The stress value increases to the area just above the corner of the piece and then decreases. This work can be further extended by using different die angles, punch radii and die clearances.

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