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FINITE ELEMENT ANALYSIS OF BLANK DESIGN OPTIMAL TO PRODUCE A TRIANGLE CUP BY DEEP DRAWING PROCESS

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ABSTRACT

The production process of a triangle cup is very difficult method, due to the occurrence violent deformations at a narrow places of the forming region, as a result of non-uniform distribution of hoop compressive stresses and radial tensile stresses, so expected a lot of problems which accompany the forming. The most important is the surplus metal that composed at cup corners, because of the non-homogeneous flow of metals during entry into the die, so appear ears at the upper edge of the cup.

To reduce that defect as little as possible, simulation model has been built by program (ANSYS 15) of deep drawing, and modify the blank from circular shape to triangular shape with a gradient corner radii (20, 28, and 35)mm. It was placed at opposite place to the draw tool form.

The effect of the blank form on the required drawn force, distribution of thickness and strains that associated with the forming process were also studied.

To make comparison between the experimental results and the results of simulation, it was manufacturing drawing tool with the same specifications of the simulation model.

The practical and simulation results showed that the low radii corners of triangular blank lead to failure of deep drawing, especially at radii corners (20 and 28)mm. While the best shape of the cup by used blank with corner radius 35mm, that required less force of drawing, and better distribution of the metal thickness and the strains.

KEYWORDS: Deep Drawing, Blank, Simulation, ANSYS-15,Triangular Cup.

1. INTRODUCTION

Deep-drawing process, which is the way in the manufacturing of intricate shapes from the sheet metal in many industry such as automotive, aerospace, domestic device and so on ".some time ago, the approach by trial and error is the conventional way to investigate and develop the condition of this process and all sheet metal forming. However, simulation of design has offered itself as a very important part in today's forceful world (Oden, 2006; Thaweepat and Jian, 2007). Finite element analysis method is very influential and extensively means for sheet forming process investigations, (Chenot and and F. Bay, 1989; Belytschko, 2000) such as, forming of U-shape channel (Taylor and Cao, 1995), forming by multistage of deep drawing (Esche and Altan, 1996), Forecasting method of tearing and wrinkling in deep drawing process, (Cao and Boyce, 1997).

To accomplish the manufacture success of deep drawing process, there is a requirements related with tool design, conditions of forming, and metals. It is attractive that the design of the blank is frequently ignored by many process designers. Therefore, this work is intend a comparison study on how the design of blank influence on quality of the deep drawing process.

There are many numerical analysis have been projected to forecast the optimal blank shape. Iseki and Murota, (1986) have anticipated the numerical model of noncircular shell drawing process to find out the form of the blank that can be shaped into a cup of regular height. Kim and Kobayashi, (1986) have projected a geometrical design to find out the curve shape of the blank for rectangular shell drawing. They accomplish this by computing the flow lines of the substance nodes in the blank throughout drawing. Toshihiko and Senga, (1987) have used so far a further inventive design for this reason. They begin with a shell having the wanted geometry properties and then "based upon a slip line field theory", and by backward steps to get the initial blank shape. Gloeck and lange, (1983) improved a numerical design by plane strain slip line field theory" to forecast the blank geometry of stamping process.

2. THEORETICAL CONSIDERATION

2.1. Strain analysis

It is generally find out the initial strain over the section in the study of any process. This can be done by measuring a grid or by investigation of the geometric limitation exerted on the component.

The "principal strains" at the ending of the process are;

$$\varepsilon_1 = ln\frac{d_1}{d_0} \quad (1)$$

$$\varepsilon_2 = ln\frac{d_2}{d_0} \quad (2)$$

$$\varepsilon_3 = ln\frac{t}{t_0} \quad (3)$$

where, ε1 is a "radial strain", ε2"circumferential strain", and ε3 "thickness strain".

The volume constancy condition requires that:

$$\varepsilon_1 + \varepsilon_2 + \varepsilon_3 = 0 \quad (4)$$

Deformation is restricted to the region under the punch, at once after touch between the blank and the punch. As the punch moved, the metal in this area is stretch-formed with overlap bending above the curved edges of the die and the punch.

It can be calculate the effective strain (equivalent strain) by the following equation, (Lange, 1985).

$$\varepsilon_{eff} = \sqrt{\frac{2}{3}\left(\varepsilon_1^2 + \varepsilon_2^2 + \varepsilon_3^2\right)} \quad (5)$$

2.2. Numerical analysis

The program of ANSYS-15 is a influential and multi-function investigation tool that can be used in a extensive range of engineering regulation, therefore we selected element "SOLID45" is applied for the 3-D modeling of solid structures. The deep drawing process with three-dimensional was modeled as shown in Fig. 1.

After the construction geometric of model .Software of program automatically subdividing the model into small member of simple profiles "elements" attach at regular points "nodes". Fig. 2 illustrates the most excellent mesh of the blanks which applied to the imitation of the drawing operations.

3. FEATURES EFFECTING ON DRAWING

There are many features which effect on the deep drawing process, and they have the major role in the accomplishment this process. The most significant of them as follows:

3.1. Die /punch profile radii:

The rim radius of the initial drawing die, over which the blank drawn is extremely significant. The rim radius (Rd) as shown in Fig. 3, typically variety from (4 to 10) times of the sheet thickness, (Eshel and Johnson, 1986).

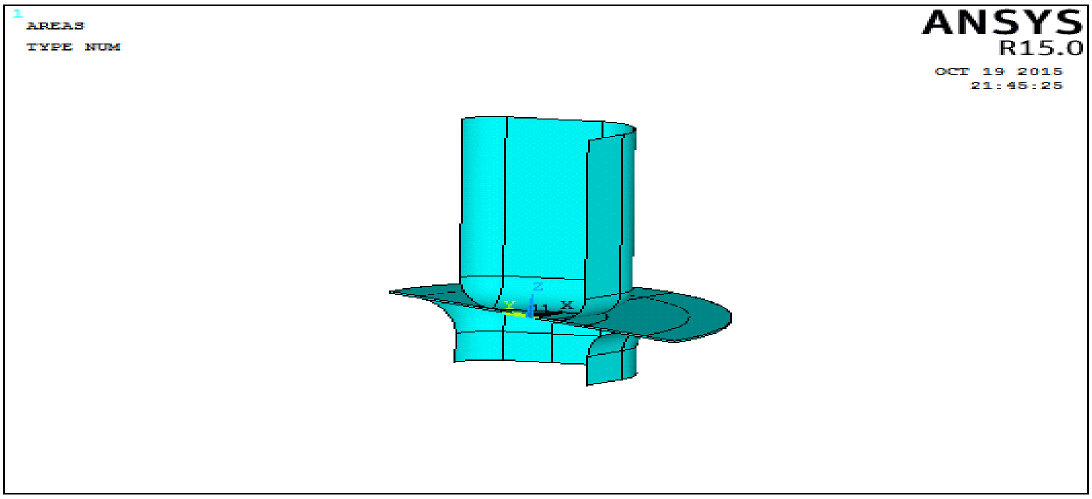


Fig. 1. The model of drawing tool which used in a simulation.

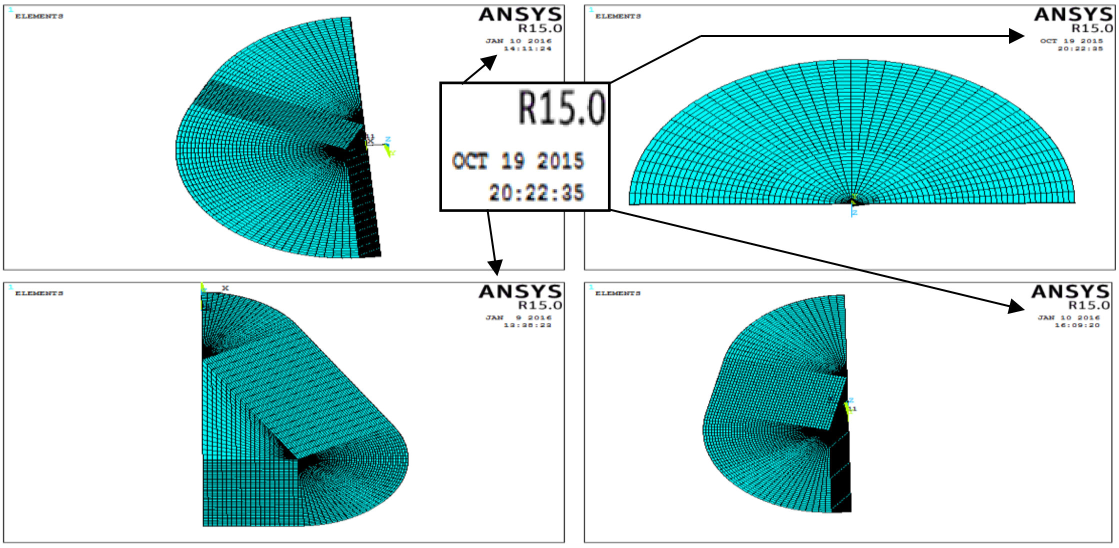


Fig. 2. The mesh of different blank which used in a simulation.

3.2. Thickness of blank:

Blank thickness can be regard as closely joined with the blank holder force. The raising of the metal thickness has some improvements that cause increase the opposition of wrinkling, (Harpell, 1997).

3.3. Drawing and redrawing forces

The force of drawing is determined based upon the equilibrium between the tensile strength of the metal and the drawing force .When the drawing forces arrive at or go above

the ultimate strength of the shell, the metal close to the failure, and when the greatest drawing force is below the strength of the shell, subsequently the drawing process can carry on till without flange cup is drawn, (Hsu and Lee, 1997).

3.4. Speed of Drawing

Speed of drawing is the rapidity of the penetration punch throughout the blank. In all-purpose the speed of drawing should be less for stiffer and more for malleable metals.

4. EXPERIMENTAL WORK:

4.1. Blank material

The major significant substance to avoid a collapse of the sheet metal forming are metal kind and their properties. Low Carbon Steel is extremely suitable in sheet metal forming, therefore it is preferred. A "1008-AISI Low Carbon Steel" with thickness of 0.7mm is employed in this work, and its "chemical composition" are illustrate in the Table 1.

Table 1. Chemical composition of Low Carbon Steel (1008-AISI).

C%	Mn%	Si%	P%	S%	Cr%	Ni%	Mo%	Al%	Co
0.053	0.187	0.009	0.014	0.003	0.015	0.028	0.003	0.031	0.005

4.2. Anisotropy

To determine the properties and anisotropy of "Low Carbon Steel" sheet, a tensile test was achieve on samples which were cutting by EDM wire cutting in the trends of (0º, 45º and90º) with the direction of rolling. The results of the tensile test "of "Low Carbon Steel" and anisotropy are included in the Tables 2 and 3 respectively.

Table 2. Mechanical properties of low carbon steel (1008-AISI).

Rolling direction	Yield stress σy (Mpa)	Ultimate stress σu (Mpa)
0°	148	270
45°	195	280
90°	190	275
Average	178	275

Table 3. The values of anisotropy concerning with rolling direction.

Material	r 0°	r 45°	r 90°	Average anisotropy r'	Planer anisotropy ΔR
Low carbon steel 1008-AISI	1.21	1.03	1.903	1.293	0.527

4.3. Tool design:

The punch and the die are manufacturing from tool steel with a triangle shape as shown in Fig. 3.

4.4. Blank design:

The blanks were cut as a triangle shape with gradients radii of its corners (35, 28, 20) mm ,and it can be computed the quantity of strains by employed a blank with grid circles having radii 10, 15, 20, 25, 30 and 35 mm and 12 cross lines with angle 30° as illustrate in Fig. 4.

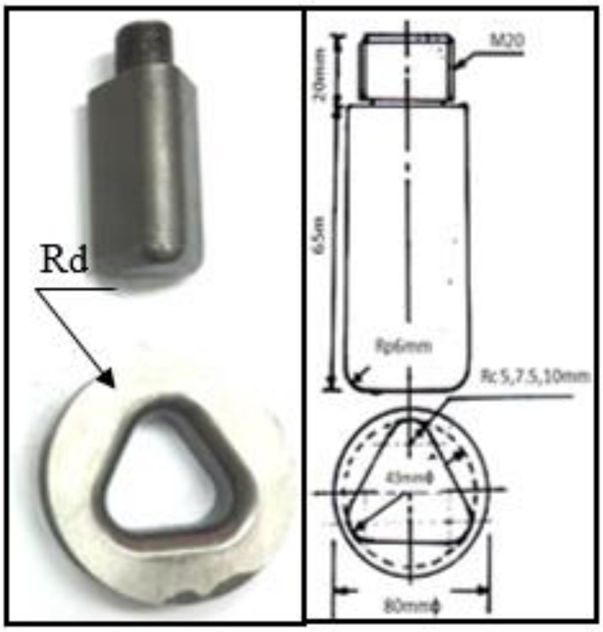


Fig. 3. A triangle tool of deep drawing.

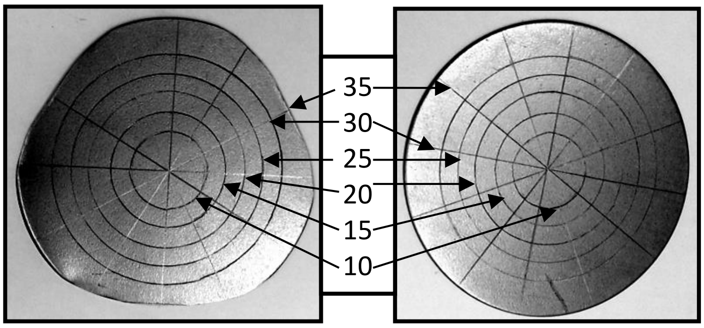


Fig. 4. The blanks.

5. THE RESULTS

The results of both the practical experiments and simulation were show that the required force of the drawing operation be less when used triangle blank has been corner radius 35mm, with comparing it with the required force for the drawing of the circular disk, as shown in Fig. 5.

Fig. 6 shows a regular distribution of the metal thickness from the center of the cup to the top edge toward the cup corner, when used a modify blank as a result to not extreme accumulation of the metal, which occurs at the entrance of the draw die in case of used the circular blank due to increased the circumference compressive stresses. Fig. 7 illustrates the distribution of radial strain from the center of the cup to the top edge toward the cup corner, which that generate due to the tensile stress , where these strains be less when used a modify blank with corner radius 35mm as a result of low required drawing force.

Fig. 8 shows the distribution of thickness strain, where these strains were homogenous in the forming region due to not accumulation at a narrow places of the die by using a modify blank. Fig. 9 shows the hoop (circumference) strain, which occurs due to the circumference compressive stresses and lead to push the metal into the die cavity, where these strains be more regular when used a modify blank with corner radius 35mm. Fig. 10 illustrates the distribution of effective strain, which is the result of the three previous strains that also be less in case if used a modify blank.

The results also show that the decreasing in the corner radii of the triangle blank lead to the failed triangle cup production in deep drawing operation, as shown in the Fig. 11, due to push the metal and more flow which occurs at the narrow regions of the tool corners , Where would be a little formation by bending and therefore cannot get to the final shape of triangle cup.

The best form of the triangle cup without earing can get it by using a modify blank with corner radius 35mm,when compared with the triangle cup that produced from a circular blank, as shown in the Fig. 12 .

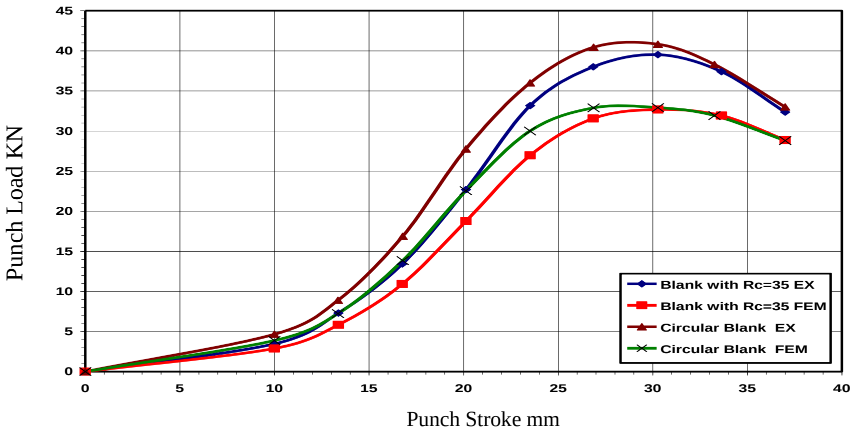


Fig. 5. Effect of the blank shape on the required draw force.

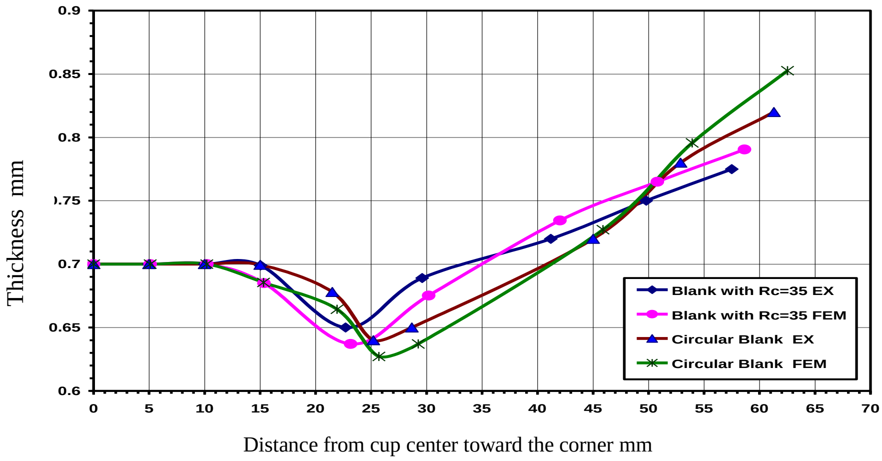


Fig. 6. Effect of the blank shape on the distribution thickness.

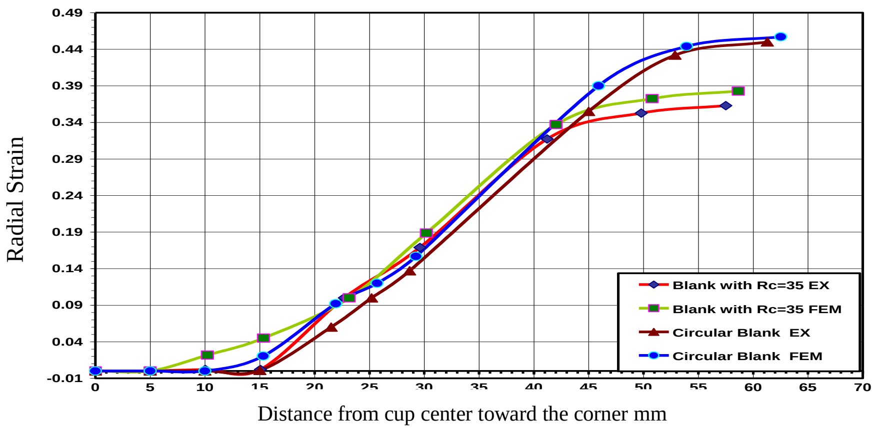


Fig. 7. Effect of the blank shape on the Radial strain.

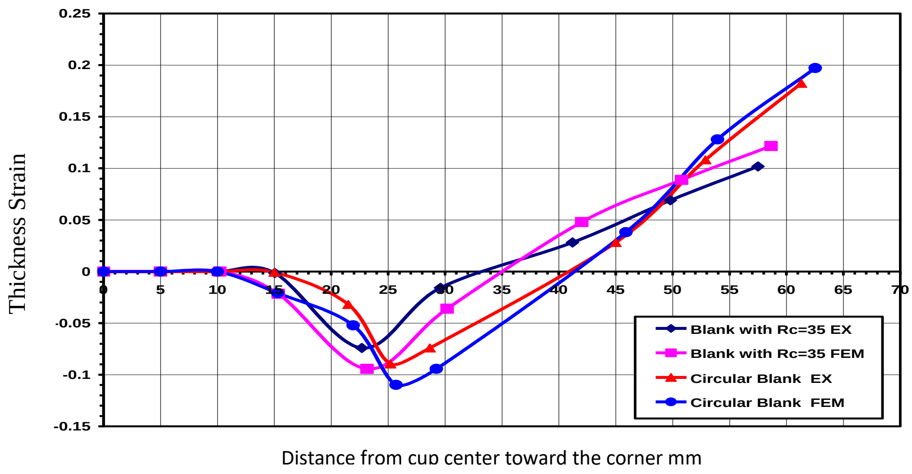


Fig. 8. Effect of the blank shape on the Thickness strain.

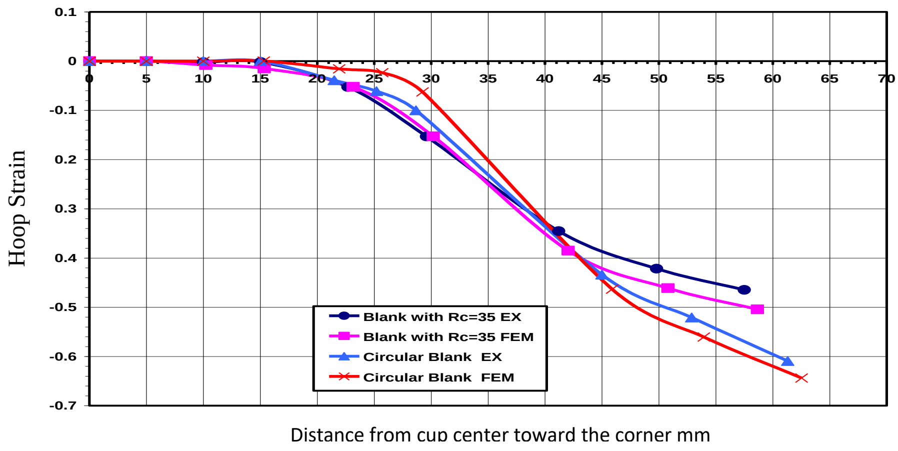


Fig. 9. Effect of the blank shape on the Hoop strain.

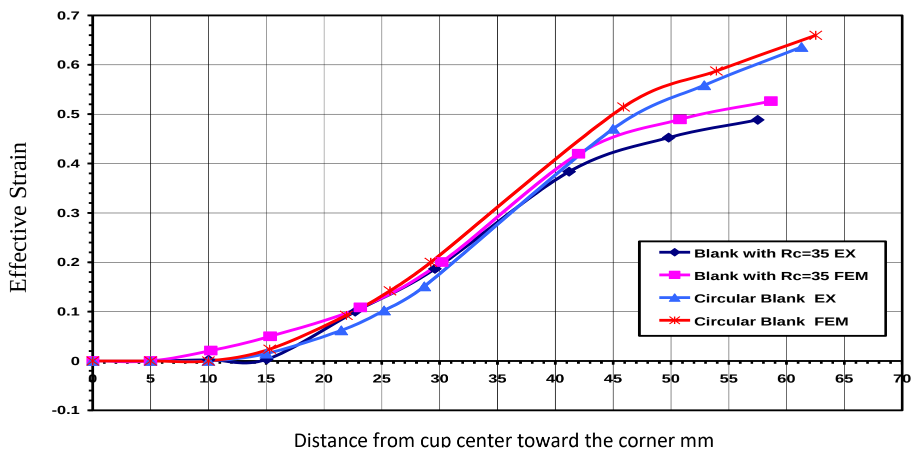
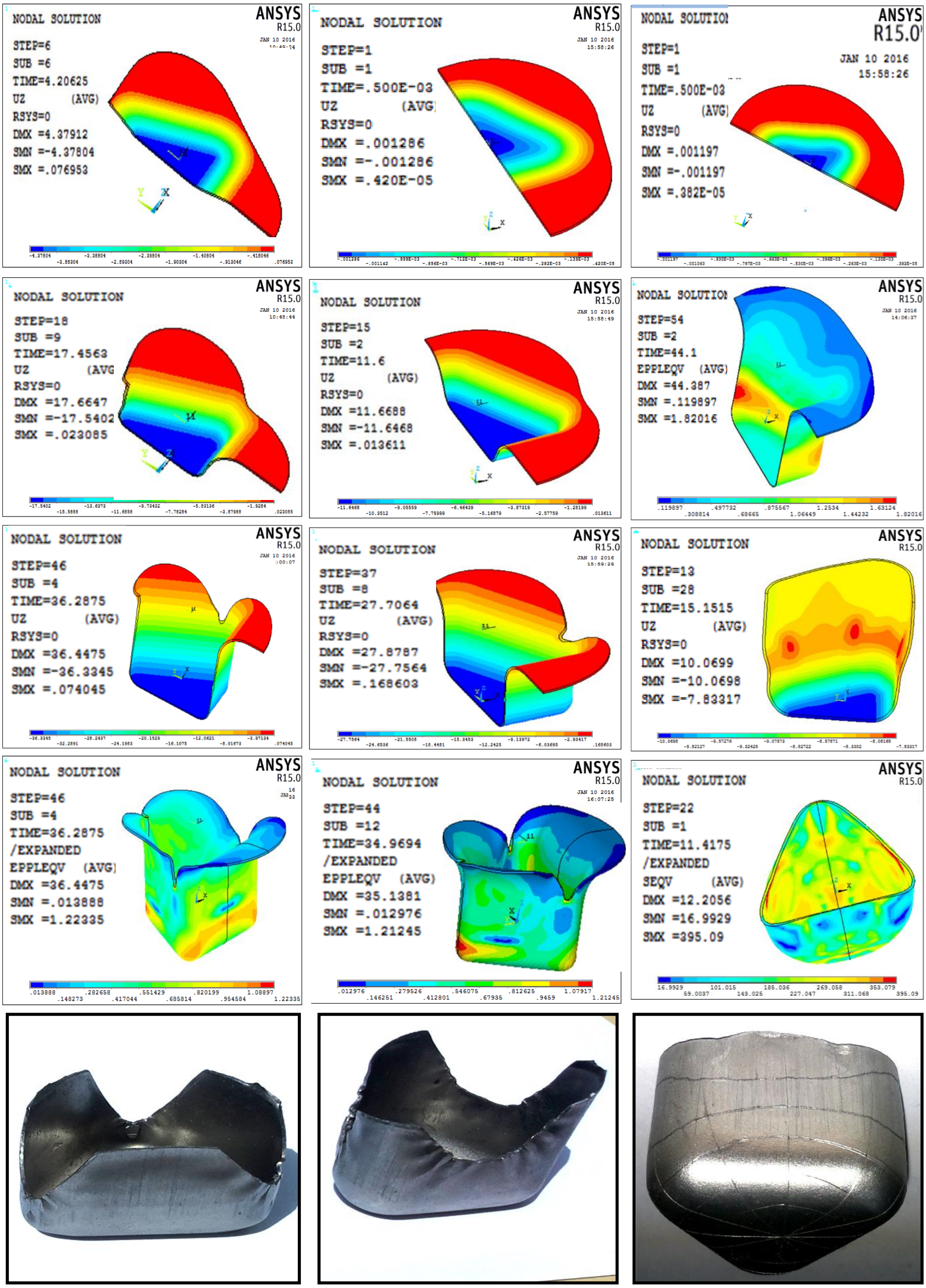


Fig. 10. Effect of the blank shape on the Effective strain.



-C- -B- -A-

Fig. 11. The steps of producing triangle cup with different blanks by simulation and experimental test; A-blank with corner radius 35mm, B-blank with corner radius 28mm, C-blank with corner radius 20mm.

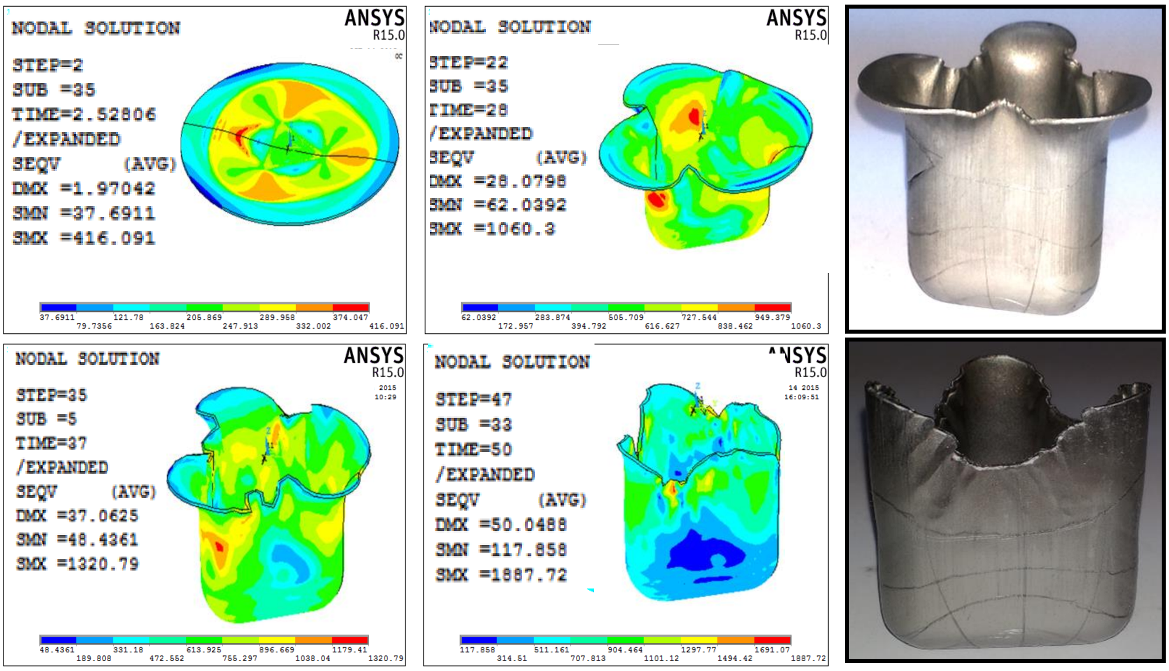


Fig. 12. The steps of producing triangle cup from a circular blanks by simulation and experimental test.

6. CONCLUSIONS

Through this study, it can be concluded that:

1. To get the best shape of triangle cup by using triangle blank with corner radius 35mm.
2. Use a triangular blanks with small radii of its corners lead to failure deep drawing operation of triangle cup.
3. The required force of the drawing process be less when used a modify blank with corner radius 35mm.
4. Best distribution of the wall thickness of the cup occurs when used a modify blank. Dispensing of the complementary operations for the final products when used a modified blank.

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