2D AND 3D AXISYMMETRIC DEFORMATION OF A CYLINDRICAL PIECE

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1- INTRODUCTION

Until few years ago, design of sheet metal forming was based on knowledge through work experience and expensive trial and error process.

Nowadays the use of numerical simulations in different phases of the sheet metal forming process are performed using finite element analysis (Ranganath et al, 2012).

Different codes are available for finite element analysis in metal forming such as Abaqus, Dynaform, Nike 2D, Ansys, etc.

Deep drawing is the metalworking process used for stamping flat sheets into cup-shaped forms, where the metal is subjected to different types of deformations (Dieter, 1961).

The aim of this work is conduct numerical simulations to verify the deep drawing process and the shape of the final stamping component of a simple profile of a sheet metal geometry.

To evaluate the design of sheet metal forming, a nonlinear dynamic explicit numerical model was developed using two models: a 3D quarter and a 2D axisymmetric finite element model, due the geometry and loading conditions symmetry to reduce the computational time processing.

The numerical simulations showed the shape deformation occurring after start the process and provided detailed quantitative information about expected weakness of the resulting piece.

2- OBJECTIVES

In order to assess the stamping performance of the cylindrical sheet metal piece, different numerical simulations were performed in the finite element code, starting from a Benchmark problem.

The proposed numerical model intents to simulate the stamping process, as a practical problem with industry interest, and to evaluate the mechanical stress and deformation in stamping piece.

In all simulations the complete die-face design composed of the punch, binder and the die geometry is assumed to be rigid components. The blank material is the high strength steel of thickness 1mm.

Different types of analysis were produced using: 3D quarter model with Solid 164 and Shell 163 elements; 3D quarter model only with Solid 164 elements and 2D axisymmetric model with Plane 162 element.

The program is based on the explicit dynamic finite element (FE) method and incorporates the dynamic characteristics of the process.

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3- MATERIALS AND METHODS

Carbon steel plate material SAE-AISI 1008 for sheet metal blank stamping is used. The properties are summarized in table 1.

Table 1 – Material properties for steel alloy (AISI 1008).

Properties	Sheet metal blank
Density (kg/m³)	7850
Young's Modulus (GPa)	210
Poisson's ratio	0,3
σ_y (MPa)	180 (180 to 310)
σ_u (MPa)	330 (330 to 370)
K (MPa)	660

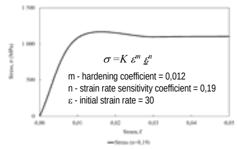


Figure 1 - Stress-strain Ramburgh-Osgood curve.

The most relevant dimensions considered of the punch (A), blank holder (B), sheet metal blank(C) and die (D) are shown in table 2, (Evangelista, 2000).

The blank then has the same weight as the cup. A blank of correct thickness would be cut to the diameter necessary to produce this weight (Gyadari, 2013).

Several formulas are available for calculating the blank diameter:

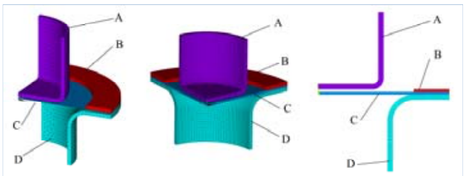
$$D_b = (D_p^{\ 2} + 4\, D_p\, h)^{1/2}$$

Table 2 – Basic geometrical parameters..

Parameters	Dimensions in mm
Punch diameter, D_p	50
Punch nose radius, $R_p = 4\,t$ (as a start)	4
Punch thickness	4
Cup height of the first draw	25
Cup total height, h	29
Clearance between punch radius and die radius, $C \pm = 1{,}1\,t$	1,5
Sheet metal blank diameter, D_b	100
Sheet metal blank thickness, t	1
Die profile radius	26,5
Die shoulder radius, R_d ($4\,t = R_d = 8\,t$)	8
Die cavity height	29
Blank holder radius	36,5
Blank holder thickness	2
Measures of drawing	
Drawing ratio, DR=D_b/D_p << 2 (only one stage)	2
Reduction, $r = (D_b - D_p)/D_b$ << 0,5	0,5
Thickness to diameter ratio, 100 x (t/D_b) >> 1%	1%

The input die assembly model (die, blank, blank holder and punch) were constructed in pre-processor using tool CAD-geometry in the FEM program. After that, a fine meshing is created.

Figure 2 represents different meshes used in this work.



(I): 3D quarter: Solid164 (8nodes) / Shell163 (4nodes) (II): 3D quarter: Solid164 (8nodes)
(III): 2D Axisymmetric: Plane162 (4nodes)

Figure 2 – Different meshes of die assembly, (A-Punch, B-Binder or Blank Holder, C-Sheet metal blank, D-Die).

An approximate equation of the maximum drawing force F (in N) or punch load was applied:

$$F = \pi\, D_p\, t\, \sigma_u\, (D_b/D_p - C)$$

C is a constant between 0,6 to 0,7. The drawing force F varies throughout the downward movement of the punch, usually reaching its maximum value at about one-third the length of the punch stroke. A factor of safety should be taken. In the study case the draw force was equal to 80,8kN (=67,4kN x 1,2).

A holding force was applied directly on the blank holder, usually represents 33% of the drawing force (Fh=33% x 80,8=26kN), (Kumar, 2016). According the dimensions and the material, the calculated holding force was equal to 26kN.

4- RESULTS

The main objective is to produce a cylindrical cup of 50 mm diameter and 25 mm deep in 0,015s.

Deformed shapes of the blank at different drawing depth are presented in figure 3, for each numerical model.

Models (I) (II) and (III) were simulated with a complete die assembly including the blank holder and the effect of the applied holding force. Also, only the Model (I) was simulated without the blank holder part to verify the flange wrinkling effect during the sheet metal forming.

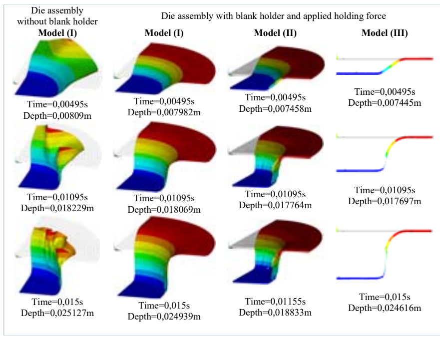


Figure 3 - Different deformed shapes of the blank.

It was observed that the model (I) represents the total depth circular cup drawing. With model (II) only 18,8mm in depth is obtained. 2D Axisymmetric Model (III) permits to calculate the cup depth of 24,6mm, however the deformed thickness sheet metal decrease significantly.

Figure 4 represents the distribution of equivalent plastic strains for successive trails of the stamp falling in time instants.

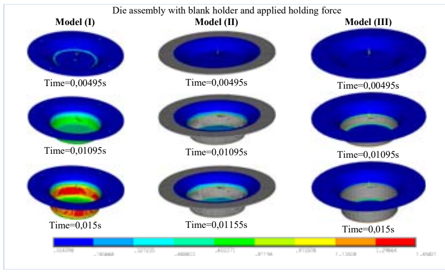


Figure 4 - Equivalent plastic strain in expanded deformed shapes of the blank.

Maximum plastic deformations are observed with red colour region or in grey colour with higher values than model (I).

The blue colour represents minimum strains in the sheet metal blank.

In this study, generally maximum strain occurs on the lateral wall cup where tension in side wall is higher.

5- CONCLUSIONS

The results from the numerical simulations produced comparisons between all types of finite element models.

There was a good correlation between all different simulations until time instant to obtain a cup of 18mm drawing depth.

This study shows the finite element procedures for the sheet metal forming process and presents the performance of the use of axisymmetric conditions in the balance of the computational requirements against the desired accuracy of the results.

With numerical simulations it is possible to observe the quality of the piece according the thickness distribution, and also detects some defects like wrinkling, crushing and tearing material.

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