

The analysis of the parameters for deep drawing of cylindrical parts

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Abstract. Deep drawing is a very important metal forming process. Thin steel sheet is important material for manufacture of numerous products with deep drawing and stamping. Cold working provides also the possibility of making parts of various shapes, from the simplest to those with a high degree of complexity whose execution through other methods is uneconomical, difficult and sometimes even impossible. In this paper it is analyzed both experimentally and with the help of the finite element, the behavior of the blank during the cylindrical cup deep drawing process, using the ANSYS software program and the finite element method. A comparison is realized between the experimental and the analytical results, elaborating a representative set of problems that analyze the variation of the die punch clearance, movement of the punch and with or without lubrication. The results of the research are useful in developing a sensible design of experiments.

1 Introduction

Cold deformation is one of the modern methods, widely used in machine building and, in particular, in the construction of motor vehicles, aircrafts, machinery and electrical appliances, fine mechanics, agricultural machinery and tractors, etc.

The process of metal processing by plastic deformation, respectively the deep drawing process, is an extremely extensive field of research [1]. This is due to the fact that the share of the volume of metal processed through these processes is constantly increasing, to the detriment of the machined ones. Thus, in highly industrialized countries, the share of the production of the parts by deep drawing is about 50% of the total of the processed parts.

Obtaining the parts through the plastic deformation process determines the following requirements to be fulfilled:

- increasing the competitiveness of the products by ensuring their quality;
- increasing the competitiveness of the producing enterprises by ensuring the best quality-price ratio [2].

Regarding the above-mentioned requirements, it is necessary to analyze the plastic deformation processes through highlighting the problem in order to ensure the required

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quality of the obtained products and the grouping of the cold plastic deformation processes by correlating different criteria so that their approach through their reduced models can be achieved. This approach, according to the latest studies, seems to be particularly important in order to ensure the optimum price-quality ratio [3].

The deep drawing process is complex because it is influenced by a multitude of factors, which has created the premises of some researches made by various scientists who have approached different aspects regarding the materials from which the semi-finished product is made, the speed of the process, the type of finished part, the active elements of the die and punch, etc. [4].

The instability phenomena which occur during the deformation process of the sheets are determined by the action of some stress forces which are unevenly distributed over various sections of the part. These phenomena are specific to deep drawing and stretching operations (necking and wrinkling).

The deformation of a body is composed of elastic and remnant deformation. The state of a body in which the remnant deformation has relatively high values comparing to the elastic ones, without a visible weakening of the bindings between the particles, is called plastic deformation.

When the remnant deformation is smaller than the elastic deformation, before the occurrence of the fracture, there is the so-called frail (breakable) state of the body. The state of a metal or an alloy depends on the concrete conditions of the deformation process (temperature, load deployment speed, existence or lack of stress focusers, etc.)

2 Material and method

At the beginning of the experiments, the cutting of the 1 mm thick sheet is made in the form of discs with a diameter of 77 mm. The following tests are performed using a die - having an inner diameter of 46.2 mm, as well as punches - whose diameters range from 43.5 mm to 40.5 mm.

Preparing the hydraulic press is the next step in verifying if it is functioning properly by visually checking the hydraulic system for any leakage of hydraulic fluid, flexible hoses and oil tank. Check whether the on / off buttons work.

Attach the force measuring or hydraulic displacement dosing support, then the base plate and the die are mounted. At the end of the ram is the support of the punch, on which the punch is attached.

The resulting data is captured through the E.S.A.M. software. (Electronic Signal Acquisition Module), version 3.0, for the Windows operating system.

It was used a VISHAY - HS 100 MG7128 type force cell of 100 kN, inverter number FO21633 – USA, calibrated on 20.09.2015. For the measurements it was used a data system consisting of a laptop and the master unit – Traveller 1, model MUT – 1, 1016-S type with 8 SG-2 type tensometric amplifying channels with a transmission band of 1kHz.

In this paper is analyzed the behavior of the blank during the cylindrical cup deep drawing process, using the ANSYS software program and the finite element method.

The finite element method FEM analyzes the behavior of the blank, insuring the validation and the accuracy of the finite element program used (being able to compare the results with the experimental ones), as well as the emphasis of the main changes occurred in the material structure during deformation: the thinning degree, the stress field, the direction and orientation of the deformations, the deformation speed of the blank.

A hydraulic press HP-U60R of 600 kN was used for the experiments (Figure 1). To perform the experiments, an S235JR blank was used, corresponding to the Romanian

standard OL37-2k, in the shape of a disc with a diameter of 77 mm and a thickness of 1 mm, the mechanical properties being shown in Table 1.



Fig. 1. Picture of the hydraulic press HP-U60R used for the experiments.

Table 1. Mechanical and physical characteristics of the S235JR steel (SR EN 10025/2-2004).

Steel brand	Tensile yield strength $R_{p\ 0.2}$ [MPa]	Ultimate tensile strength R_m [MPa]	Poisson Coefficient ν_{med}	A [%]
S235JR	235	510	0.31	26

3 Results and discussions

For the analyzed S235JR construction steel, 12 experiments were performed, six experiments for each unilateral clearance (0.35, 0.60, 0.85, 1.10, 1.35, 1.85), of which three were without lubrication and three were lubricated (Figure 2).

Consequently, the experimental and finite element values obtained in the two lubrication cases (without lubrication and lubrication) are obtained by making the arithmetic average, in the case of the punch displacement value and the time required to perform the deep drawing operation.

The displacement speed of the punch is obtained mathematically in both situations both experimentally and in the case of finite element simulation. All this information on the cylindrical deep drawing process is structured in Table 2.

The lubrication of the semi-finished piece has been carried out using the Rolle Line Applicator, Shell Fenella D605 Liquid Lubricant, based on highly refined mineral oil containing polar additives and chemical active additives (chlorine-free).



Fig. 2. Pieces obtained through the deep drawing process of the steel S235JR.

To study the behavior of the S235JR material using the finite element method, it was envisaged to create a three-dimensional model that fully complies with the active element (die-punch) geometry made in the CATIA drawing program by saving the file with the *.igs extension, in order to be able import. For punch and die, the value of the element in the mesh size is 5 mm, and for the blank the element size is 1 mm resulting in a number of 15719 knots and 8837 elements.

The smaller the size of the element within the network, the more the analysis process in the simulation is validated by the results of user experiments.

Element size is also chosen based on computer performance, simulation time, user experience, simulated field, etc. In the Ansys program, you can choose the mesh type: Tetrahedrons, Hex Dominant, Sweep or MultiZone. In the present case for the analysis of plastic deformation, the optimal method and the most used method of the meshing for the cylindrical parts is the MultiZone.

The stamping force was determined by mathematical calculation when designing the finished piece. Since with the finite element method (FEM) one can track the influence of the geometry of the piece on the drawing process, the value of the stamping force could be confirmed by obtaining the geometric elements of the finished product. For finite element analysis, a coefficient of friction of 0.01 was used.

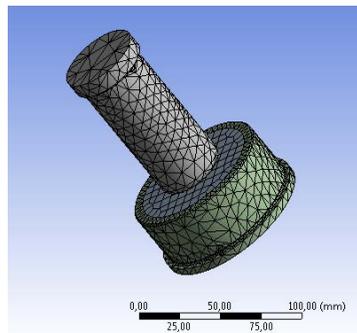


Fig. 3. The meshing of punching system - sheet metal - die in the cylindrical deep drawing process.

Table 2. Values obtained through experiments and simulation at the deep drawing process of the steel S235JR.

No. crt.	J [mm]	U/ FU	F _{max} [kN]	Experiment			Simulation		
				D [mm]	T [s]	V [mm/s]	D [mm]	T [s]	V [mm/s]
1	0.35	FU	35.25	38.85	27.60	1.41	43.51	32.40	1.34
2		U	32.34	38.02	27.95	1.36	42.58	31.75	1.34
3	0.60	FU	32.41	38.17	29.09	1.31	42.75	33.89	1.26
4		U	30.17	38.03	27.38	1.39	42.67	31.08	1.37
5	0.85	FU	30.28	40.06	15.37	2.61	44.70	18.77	2.38
6		U	28.14	39.27	15.48	2.54	44.88	20.28	2.21
7	1.10	FU	28.43	39.45	15.21	2.59	43.68	18.76	2.33
8		U	26.31	39.21	15.23	2.57	44.19	18.52	2.39
9	1.35	FU	26.16	38.93	14.22	2.74	43.60	17.83	2.45
10		U	24.22	38.28	15.87	2.41	43.26	19.25	2.25
11	1.85	FU	24.43	38.09	14.07	2.71	43.35	17.75	2.44
12		U	22.36	37.86	15.58	2.43	42.67	19.17	2.23

J = Clearance [mm] ; U/FU = with lubrication /without lubrication;
 D = Punch movement [mm]; V = Punch speed [mm/s]

The material of the blank is considered to be a continuously deformable elastoplastic medium. In the elastic field, the material is considered an axiomatic symmetric anisotropy, and in the orthotropic plastic field (the main anisotropy axes are perpendicular 2 by 2), and in the modeling with finite element, normal anisotropy will be adopted the (in the direction of drawing)

In general, the stamping force depends on the geometrical dimensions of the finished piece, and in the present work the influence of the stamping force is shown depending on the movement of the punch and the clearance between the active elements. In the finite element simulation, where the normal voltage is determined, as well as the highlighting of the critical areas, red area (Figure 4, Figure 5, Figure 6, Figure 7), in the Report Preview we can see the details regarding the movement of the punch depending on time.

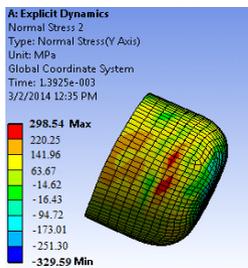


Fig. 4. Maximum normal stress for J=0.35 mm.

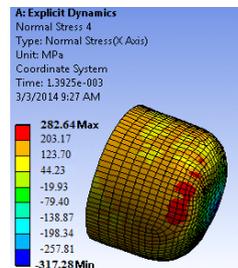


Fig. 5. Maximum normal stress for J=0.60 mm.

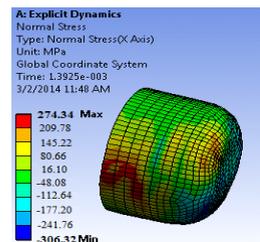


Fig. 6. Maximum normal stress for J=0.85 mm.

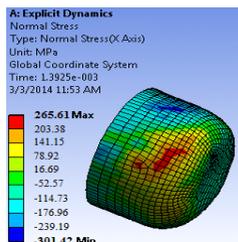


Fig. 7. Maximum normal stress for J=1.10 mm.

Figure 8 and Figure 9 highlight the variation of the maximum values of the punch movement for each unilateral clearance, obtained experimentally and by FE. According to previous researches, the variation of the stamping force depends on the entire stroke of the punch. In this paper, only the maximum value of the stamping force for each case in question was highlighted for each clearance between the active elements.

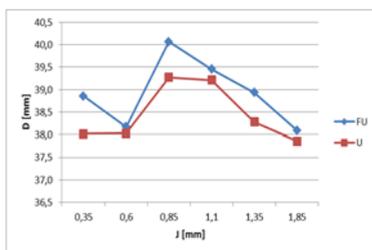


Fig. 8. The variation of punch movement according to unilateral clearance obtained experimentally, with / without lubrication.

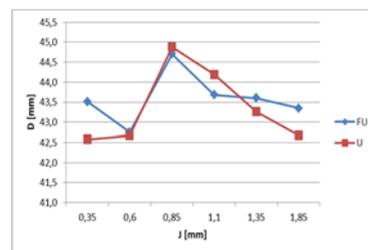


Fig. 9. The variation of punch movement depending on unilateral clearance obtained by FE simulation without/with lubrication.

In Figure 10 is observed the variation of drawing force according to punch movement having a maximum value of the 22.36 KN.

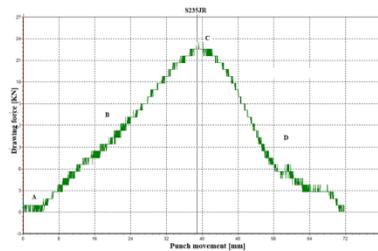


Fig. 10. The variation of drawing force according to punch movement.

4 Conclusions

A representative set of variants of the cylindrical stamping process was studied by different punch clearance values between die and die punch (0.35, 0.65, 0.85, 1.10, 1.35, 1.85 mm).

For each of the six clearances between the die and the punch, two lubrication conditions (lubrication / no lubrication) were taken into account, resulting in the twelve analyzed variants (Table 2).

There are differences in values between the experimental data and the numerical simulation for the movement of the non-lubricated punch, ranging from 9% to 12%. For the lubricated punch, the values of the experimental data versus the simulated values vary between 10% and 12%.

For the drawing speed, the values of the experimental data compared to those obtained from the simulation vary between 3% - 10%, for conditions without lubrication and from 1% up to 12%, for conditions with lubrication. The obtained differences are justified due to the fact that in the numerical simulation the materials were considered with axiomatic-symmetrical anisotropy. In fact, the properties of the blank may also vary according to the radial direction due to the rolling process.

In the analysis of the finite element, a high normal stress is noted at low values ($J = 0.35\text{mm}$; $J = 0.85\text{mm}$), of the die punch clearance, respectively low stress at high values of the clearance (Figure 4, Figure 6).

On the basis of the obtained conclusions, it is envisaged to continue the research for other parameters characterizing the deep drawing, for comparing the experimental results with the simulated results.

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