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The Energetic Aspects in Deep Drawing with Combined Restraint

C. Spiridonescu, V. Paunoiu, I. Constantin, A. Epureanu
University of Galati, Department of Manufacturing, Robotics and Welding Engineering,
viorel.paunoiu@ugal.ro

ABSTRACT

In deep drawing with combined restraint the blank is restrained in two succcesive stages. Force is one of the energetic parameter which characterizes the deformation process. In the paper are presented the experimental and numerical works regarding the influence of the die radius and degree of deformation toward the force variation. For the experimental work a transducer was designed. For the numerical experiments a finite element program was used. It was demonstrated that with increasing the degree of deformation the value of force also increases. Also, for the same degree of deformation, the increase of the die radius leads to a decrease of force. It was concluded that, for the process of deep drawing the use of a higher die radius has important advantages from the energetic point of view.

KEYWORDS: deep drawing, numerical simulation, sheet metal forming, energetic consumption

1. Introduction

In deep drawing with combined restraint the blank is restrained in two succcesive stages (figure1).

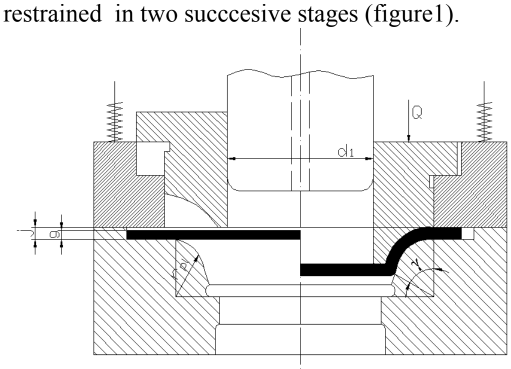

Fig. 1. *The deep drawing with combined restraint [1]*

First, the material gets deformed under the strain of the first binder plane surface, till it deforms along the die radius. Then, in the next stage, the process of deformation continues with the restraint of the blank on the plane zone using the first binder and on the die radius zone using another binder (in this case, a circular one). As it results from the figure, to avoid the material wrinkle it is absolutely necessary as the blank it to continue to be restraint with the first binder. This assures the continuity of the deformation process. On the other hand, the presence of the second binder is a result of the die design which had, in this case, a higher radius die in comparison to the conventional deep drawing.

Some of the major advantages of the process are: the presence of the second binder leading to the increase of the possibility to obtain a deep drawing ratio *m* for the first operation of about 0.42, [1, 2]; the costs with the equipments and labour are reduced for the first operation by 50% because the first two deep-drawing operations could be cumulated in only one operation; the higher radius die led to a smaller deep drawing force so the costs with energy are reduced; the durability of the die is increasing because the wear of the die is smaller as a result of the presence of a higher die radius [3].

According to [4], the pressure in the deep drawing process with combined restraint is given by:

$$q = k \cdot g^2 \frac{(1{,}5+\varepsilon_r)\sigma_r}{6\, r_{pl}^2 (1-\sin\gamma)\left(1+\dfrac{r_{pl}}{d_1}\right)} \qquad (1)$$

where: g is the material thickness; r_{pl} – die radius; ε_r – relative elongation at the material fracture; σ_r – fracture resistance of the material; γ – angle of the die radius which meet with the circular binder; d_1– part diameter; k – correction coeficient function of the material thickness.

In what follows the paper will present the experimental and numerical work for force determination.

2. The Experimental Work

The device used for the experimental study of the deep drawing process with combined restraint is shown in figure 2. The main dimensions of the active elements are presented in table 1.

Table1. *Main active elements dimensions*

Active element	Size (in mm)
Die diameter	52.25
Punch diameter	50
Radius die	15

The device is working on a 200 KN simple action hydraulic press. The circular binder is manually activated, according to figure 2, after the blank deformed along the die radius.

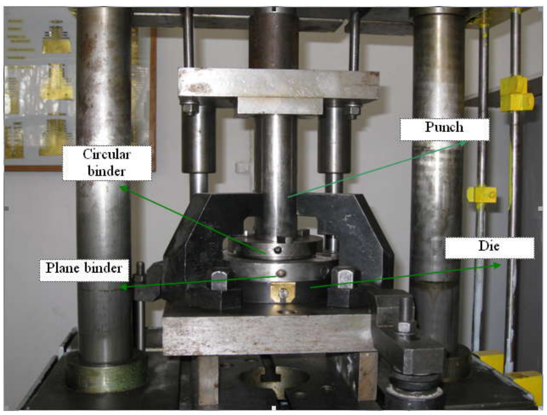

Fig. 2. *Experimental device*

For the experimental work, blanks were used from medium steel with a thickness of 0.9 mm and a yield point R_c of 196 Mpa. The blank diameters were D=106 mm, D=115 mm and D=120 mm. The deep drawing ratios *m* defined as the ratio between the part and the blank diameter, for these cases, were 0.49, 0.47, and 0.43.

Two sample pieces obtained using the method of combined deep drawing for the two deep drawing ratios are presented in figure 3.

For measuring the force variation, it was designed a transducer with strain gauges. The acquisition system Spider 8 was used for measuring the force. The acquisition system has four channels of type SR55, which assure the connection to the strain gauges.

Figure 4, presents the variation of the force for a blank diameter of 115 mm (*m* equal to 0.47) and a radius die of 15 mm. The force increases with increasing the punch moving, than it remains more or less constant and, finally, reaches a maximum of 2,5 tf when the end of the part is flowing in the die cavity. This increasing is a result of the material thickening at the end of the part.

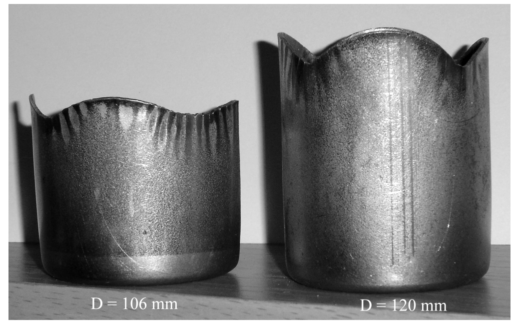

Fig. 3. *Sample pieces obtained using deep drawing, with combined restraint [2]*

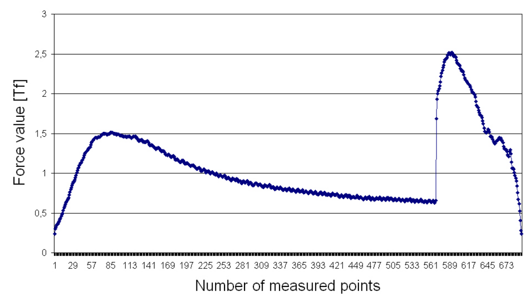

Fig. 4. *Force variation for m=0.47 and die radius=15mm*

3. Numerical Work

The simulation of the deep drawing process is carried out with the commercial software Dynaform. The Belytschko-Lin-Tsay shell element based on a combined co-rotational and velocity-strain formulation was chosen to analyze the elasto-plastic process with complex geometrical nonlinearity. The elements provide five integration points through the thickness of the sheet metal [2].

The tooling was modelled as rigid surfaces.

The investigations were based on a coefficient of friction equal to 0.1. The material used in experiments was medium steel, with a thickness of 0.9 mm, chosen from the program material database, BH180, similar as properties to the real one. The mean properties of the material were: the yield stress of 196 MPa and the work hardening coefficient *n* of 0.19. The material was assumed to be anisotropic. The *R*-value at 0^0 was 1.65; at 45^0 was 1.25 and at 90^0 was 1.80. The yielding of the material was modelled using a power law, as:

$$\sigma = K\,\varepsilon^n \qquad (2)$$

where K (MPa) is the material constant, K = 567 MPa.

The punch speed was 5 mm/second. The dimensions of the active elements were in accordance with the values presented in table 1.

In paper [1] the availability of the simulation results was demonstrated.

Table 2. *The simulation cases*

Deep drawing ratio		Radius die (in mm)	
0.49	0.43	15	18
0.47		16	19
0.45		17	20

4. Results and Discussions

Some simulation stages are presented in figure 5.

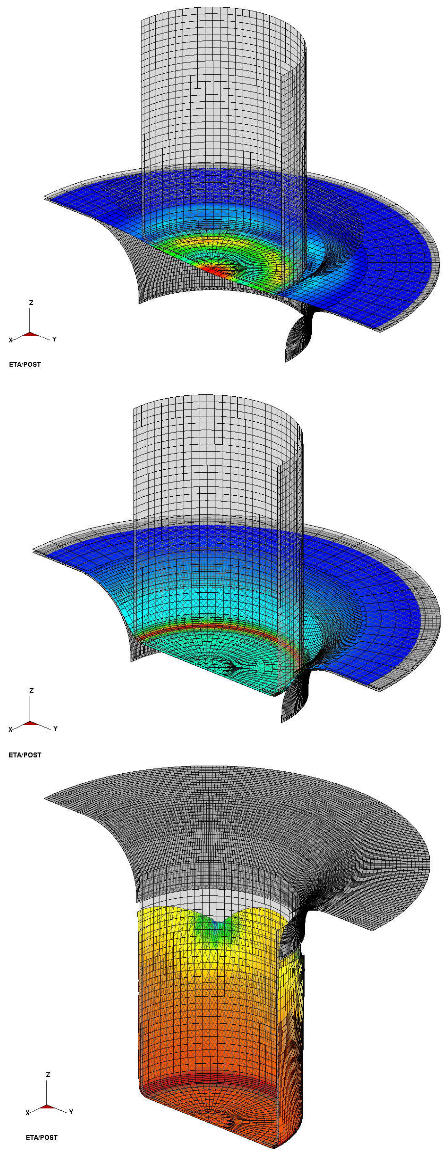

Fig. 5. *Simulation stages in deep drawing with combined restraint: top-deformation with plane restraint; middle-deformation with plane and circular restraint; bottom- final deformation*

According to these stages in figure 6 the form of the force curve is presented as being the same for all the simulation cases presented in table 2.

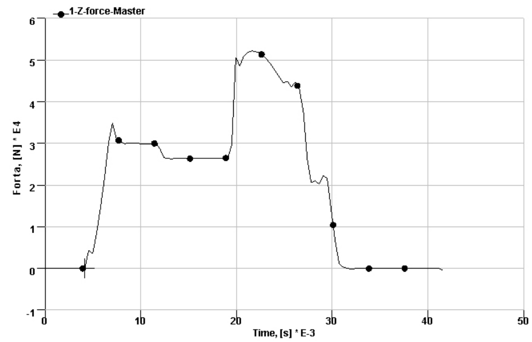

Fig. 6. *The force curve in deep drawing with combined restraint*

Figure 7 presents the force variation for different die radii and the degree of deformation, according to table 2. The arbitrary points from figure correspond to the die radius: 1 for a radius of 15 mm, 2 for a radius of 16 mm and so on, the last one being 6 which corresponde to a radius of 20 mm. Two aspects could be highlighted: first, the increase of degree of deformation leading to the increase of the force value; secondly, the increase of the die radius leading to the decrease of the force value. The last observation was demonstated by the experimental researches presented in [2] and prove that the increasing of the die radius assures better deformation conditions.

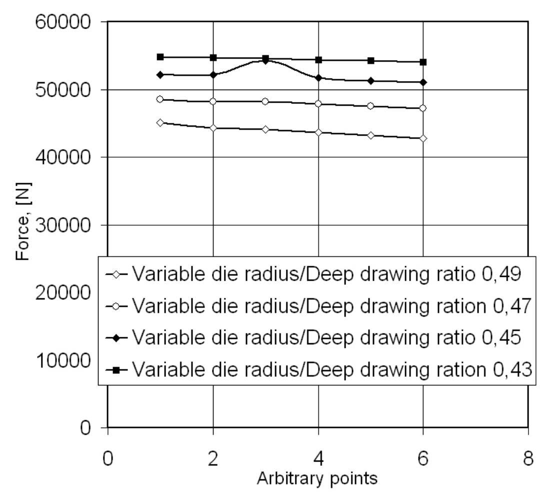

Fig. 7. *Force variation function of the die radius and the deep drawing ratio*

If we compare the value from the experimental work (figure 4) and the numerical work (point 2 from the second curve from bottom to top in figure 7) we notice a difference of about 2 tf. This substantial difference may be caused by a combination of influences of the studied parameters (friction, strain-hardening exponent, normal plastic anisotropy ratio). Also, some unexpected problems in the transducer design and the fabrication also conducted to this difference.

5. Conclusions

For estimation, the energetic consumption in any deformation process, including the deep drawing with combined restraint, the force variation could be used. Force is one of the energetic parameters which characterizes the deformation process. The obtained experimental and numerical results show that during the deformation process the force presents two maximum values, one corresponding to the restraint of the blank on the plane zone and the other one corresponding to the final moment of the part flow on the die cavity. It was demonstrated that with increasing the degree of deformation the value of the force will also increase. Also, at the same degree of deformation, the increase of the die radius leads to a decrease of force. It was concluded that for the process of deep drawing the use of a higher die radius has important advantages from the energetic point of view.

Acknowledgement

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Aspecte energetice la ambutisarea cu reținere combinată

Rezumat

La ambutisarea cu reținere combinată semifabriacatul este reținut în doua faze succesive. Forța este unul din parametrii energetici care caracterizează procesul de deformare. In lucrare, sunt prezentate rezultatele experimentale şi numerice referitoare la influența razei matriței si a gradului de deformare asupra variației forței. S-a demonstrat că odată cu creşterea gradului de deformare valoarea forței creşte. De asemenea, la aceeaşi valoare a gradului de deformare, odată cu creşterea razei de racordare, valoarea forței scade. In final, rezultă că pentru procesul de ambutisare utilizarea unei raze mari de racordare a matriței conduce la importante avantaje din punct de vedere energetic.