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NUMERICAL AND EXPERIMENTAL INVESTIGATIONS OF THE NICKEL THIN SHEETS MICRO-DEEP DRAWING PROCESS

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ABSTRACT

The increasing demands for small devices which have multiple applications in automotive industry, in chemical industry but also in medicine leads to new approaches concerning both the simulation and the experimental analysis of the material forming processes. In this paper are presented the experimental and numerical studies regarding the micro-deep drawing of Ni (99.999%) sheets. For experimental point of view the influence of punch and die radius toward the level of forces and parts quality was investigated. A numerical study was performed in order to analyse the deformation process. The obtained numerical results were validated by the experimental work.

KEYWORDS: micro-deep drawing, FEM, modelling, simulation

1. Introduction

The increase demand for the small products with multiple functions leads in the last decade to an increase of the interest of the researchers in the area of microforming. To study the process involved in microforming and its influence on the entire behaviour of the material is the main purpose of the researchers in this production area. The transfer of the know-how for the macro-processes to micro-processes was analysed by different authors [Eichenhuller, 2008]. Experimental studies on microforming of bulk material were performed by [Cao, 2004] [Eichenhuller, 2008] and their applications in case of micro-pins were analysed. In the field of sheets microforming were studied the micro-deep drawing process of different metallic materials [Saotome, 2000].

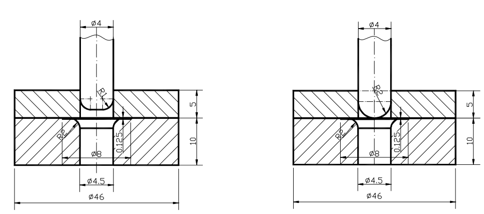
In this article micro-deep drawing process was experimentally and numerically studied. Micro-deep drawing experiments of cylindrical and spherical cups were carried out. A numerical simulations using FEM are presented for maximum force prediction in micro-deep drawing of Ni sheets.

2. Experimental equipment and material

2.1. Experimental conditions

In the last years one of the most studied subjects in terms of mechanical behaviour of metallic material was the deep-drawing process of micro parts from special materials.

The basic schema for a deep-drawing process which is used also in micro-deep drawing process is presented in figure 1. The following parameters characterise and influence the results of a deep-drawing process and their influence become more and more important in a micro-process case: blank dimensions, material properties, punch and die dimensions, punch and die radius, friction between the active elements and the blank, the gap between the active elements.



a) Cylindrical punch *b) Spherical punch*

Fig. 1. *Deep-drawing schema*

For studying some of their influences the experimental conditions was as follows: A circular sheet metal blank with 8 mm in diameter in case of a spherical cup and 10 mm in case of a cylindrical cup and the thickness of 125 µm, is placed over a die with an inner diameter of about 4.5 mm, the value of the corner radius corner radius was varied between 1 to 2.5 mm.

The blank is held in place by a ring-shape blankholder with the inner diameter of 4.5 mm. Two punches are used in the experimental device: one punch for obtaining spherical cups with the dimensions presented in table 1 and another one for obtaining cylindrical cups with dimensions presented in the same table.

Table 1. *Dimensions and geometries of the punches*

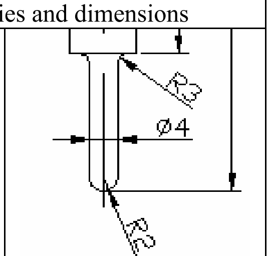
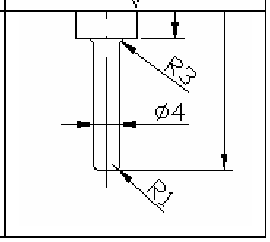
Punches geometries and dimensions	
Spherical punch	
Cylindrical punch	

Figure 2 shows the designed and desired dimensions for the cylindrical and spherical cups which are intented to be obtained in micro-deep drawing process. Dimensions and geometries of the cups which are used in the experiments and simulations are the same.

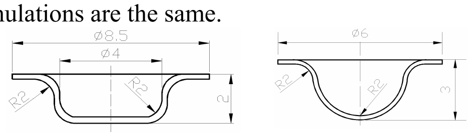


Fig. 2. *Dimensions of the deep-drawn parts*

2.2. Experimental device

The experimental device used in the experimental tests was mounted on a hydraulic press with a maximum load force of about 20tf. Figure 3 shows a photo of the experimental assembly. The deep drawing forces were measured using a force transducer mounted in the superior part of the die. The punch stroke was obtained using a device with a laser beam.

2.2. Material

The material used in this study was nickel (99.999%) with 0.125 mm in thickness. The main feature of this material is that the ratio between the thickness and the grain size is close to 1. This characteristic made possible to describe the entire mechanical behaviour of the Ni sheet by applying the knowledge from the experiments .

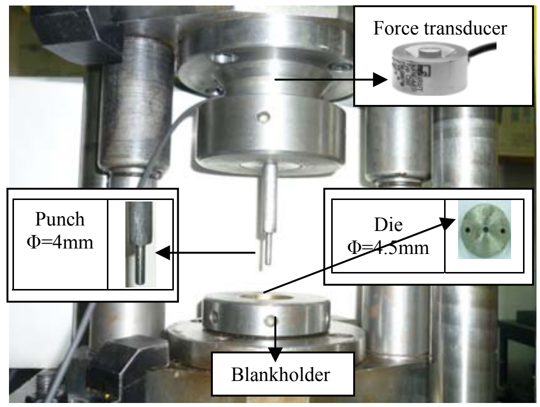


Fig. 3. *Deep-drawing die and the measurement system*

3. Experimental results

Experimental micro-deep drawing tests were carried out in the above conditions. Two types of punches and dies geometries were used in the experimental tests. Table 2 shows the microcups obtained.

Table 2. *Micro-deep drawing parts*

Die radius / Punch geometry	R1	R2.5
Cylindrical punch		
Spherical punch		

From the experimental results can be observed that the die radius has an influence on the shape of the cups. In case of the spherical geometry of the punch it can be observed that the wrinkles occurs on the flange of the cups. This behaviour can be due to the die radius.

This parameter which has an important influence in deep drawing results was specially modified in order to prove that the same behaviour occurs in both cases at conventional dimensions and in micro-scale dimensions.

The occurrence of the wrinkles when a die with a radius of about 2.5 mm was employed in experimental tests can be considered to be an effect of the reduction of the retained surface which leads to an increase of the deformed force.

A reduction of the value of the die radius with 1.5 mm leads to an increase of the deep drawing force. The wrinkle occurs in this case but it is not so visible as in case of a die with 2.5 mm radius.

The sizes of measured forces are presented in chapter 4 in order to validate the numerical simulations results.

4. Numerical simulation

Numerical simulations of micro-deep drawing process were performed in a finite element code named Lagamine, developed in departament ARGENCO, University of Liege. This finite element code it is based on a implicite integration schema.

The following conditions were used in numerical work:

1. Material

In numerical simulation were considered thin sheets of nickel with the following mechanical properties: Young modulus was 27710 MPa and Poisson ratio was 0.3.

2. Behaviour law

It was considered a Swift law for the simulation. This law was defined using a stress-strain evolution. The values true stress-true strain in five characteristic points of the tensile curve are presented in table 3. Data were experimentaly obtained after tensile tests. Tensile tests on nickel thin sheets were carried out in University of Caen.

Table 3. *Mechanical properties for the nickel thin sheets in terms of true stress true strain*

True stress (MPa)	True strain
27,71	0,001
115,54	0,030
272,31	0,100
405,25	0,200
555,34	0,800

3. Tools

The tools were considered as rigid bodies with a friction ratio between tools and material about 0.1.

4. Finite element

In order to mesh the material solid finite element were used. These elements have 4 nodes and one integration point.

5. Contact element

For the contact behaviour between blankholder and and blank on side and on the other side between tools and blank were considered finite element CNTCP [7] with one single integration point and 2 nodes.

The influence of the punch geometry on the value of the Von Misses equivalent stress can be observed in figure 9 and 10 and it can be concluded that the value of this stress depends on the punch geometry.

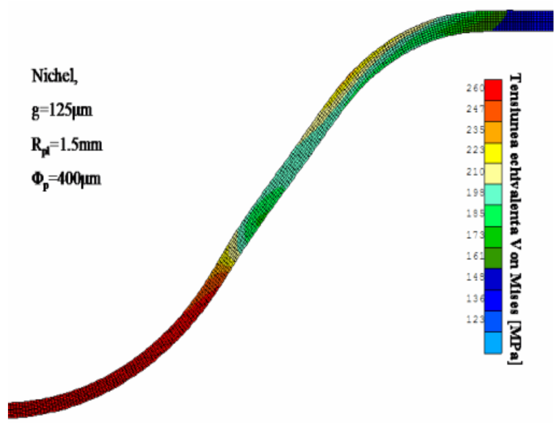


Fig. 9. *Von Misses equivalent stress through a spherical microcup (Lagamine)*

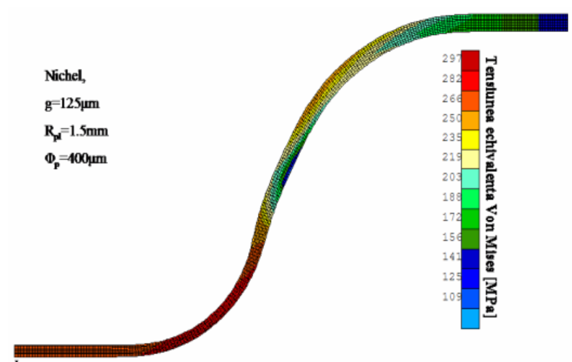


Fig. 10. *Von Misses equivalent stress through a spherical microcup (Lagamine)*

An increase of this stress it was observed in case of a cylindrical punch. This increase of about 50MPa can be explained as an effect of the contact area dimensions. The contact area dimensions have an influence on the material flow this can be observed at the bottom part of both microcups as a thinning.

The influence of the punch geometry on the value of the micro-deep drawing force was plotted in figure 11 and 12.

The geometries of the dies were the same the only difference was that the active part of the punch was changed.

The active part of one deep-drawing punch was flat and another one was spherical.

From both the experimental data and the numerical results can be concluded that the punch geometry have an influence on the value of the micro-deep drawing force.

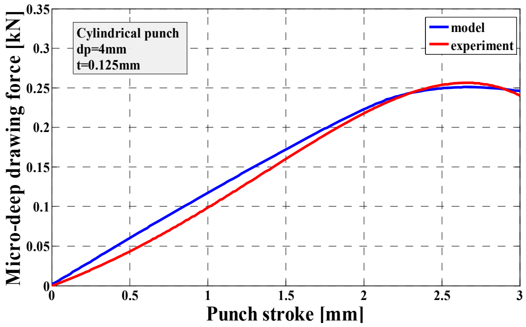


Fig. 11. *Experimental data versus numerical results of the micro-deep drawing of a cylindrical cup*

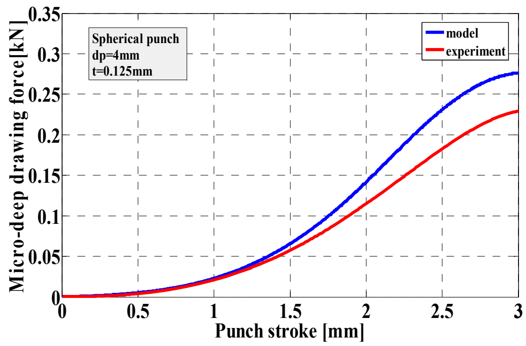


Fig. 12. *Experimental data versus numerical results of the micro-deep drawing of a cylindrical cup*

The punch geometry influence also the dimensions of the contact area which have influence on the material flow explained in figure 9 and 10 as a thinning in the bottom part of the microcups.

5. Conclusions

1. Punch shape has an influence on the pattern of the deformation.

2. From the experimental and numerical results it can be concluded that the geometry of the punch has the main influence on the micro-deep drawing force.

3. The radius of the deep drawing die has also an influence on the deformed force also. This influence can be observed on the surface of the obtained microcups. These surfaces were affected of the wrinkles occurrence which are more pronounced in case of die die radius about 2.5mm than in case of a small die radius of about 1mm.

4. The forces variations between experiment and simulation are similar for the deformation with a cylindrical punch and some differences appear for the deformation with a spherical punch. The friction is the main factor which affects the numerical results in this last case.

It can be concluded that the simulation are in accordance with experimental results.

ACKNOWLEDGEMENTS

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Investigații experimentale şi numerice ale micro-ambutisării tablelor subțiri de nichel

- Rezumat -

Creşterea cererii de mici dispozitive utilizate în diferite aplicații din domenii industriale precum industria auto, industria chimica dar mai ales în medicină a condus către noi abordări în ceea ce priveşte analiza numerica prin simulare cât şi analiza experimentala a proceselor de deformare plastică. În această lucrare sunt prezentate rezultatele experimentale şi numerice obținute la micro ambutisarea tablelor subțiri de nichel (99,999%). Din punct de vedere experimental a fost investigată influența razei poansonului şi a matriței asupra nivelului forțelor şi a calității pieselor ambutisate. A fost efectuat un studiu numeric privind analiza procesului de deformare. Rezultatele numerice sunt validate de rezultatele experimentale.