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FE-SIMULATION AND ANALYSIS OF FRICTION CONDITIONS IN THE DEEP DRAWING TEST

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Abstract: *The friction conditions in the deep drawing process are a major factor affecting the amount of the punch force, the tools wear and also the product surface quality. This paper presents an analysis of the influence of friction conditions on the punch force in deep drawing test of a cylindrical cup. For this a finite element model for simulation of deep drawing test was build. The variables in this study were the coefficient of friction between blank and tools and the blank holder force. A DC06 cold rolled steel sheet with 1 mm thickness is considered in this study.*
Key words: *Deep drawing test, Friction conditions, FE-Simulation, Punch force, Blank holder force.*

1. INTRODUCTION

The cold forming processes of sheet metal is a very important segment of the manufacturing, worldwide. Only in the United States of America it is estimated that over 100 billion $ is spent annually for design, manufacturing and assembly of parts produced by cold forming. In the larger industries such as automotive and aerospace, the cold forming is considered the most critical component of achievement of a product [1].

The tribological conditions in the contact zones between the blank and tools surfaces play an important role in the establishment of the procedural limits of the cold forming process. The friction in different contact areas affects the flow of the material into the space between tools and is used deliberately to control the forming process [2].

In order to study the friction conditions in the sheet metal forming, there are a large variety of friction tests. Studies related to the tribological tests were made in the references [3], [4]. Bay et al. [5] proposed a classification of the friction tests used to study the behavior of the lubricants in the sheet metal forming, in the following two categories:

- technological test;
- simulative tests.

The technological tests are characterized by the fact that the typical operations of the cold forming are used without the changing of the basic kinematics of the process, while the simulative tests are tests that try to model the tribological conditions that occurs in the cold forming processes, in order to study the friction and/or lubrication in a controlled manner. Simulative tests are therefore characterized by significant deviations from the kinematics of the forming process performed in industry.

The aim of the paper is to analyze the deep drawing test of a cylindrical cup using numerical simulation in order to determine the influence of friction conditions on some characteristics as follows:

- the analysis of the influence of friction condition on the punch force;
- the analysis of the influence of blank holder force on the punch force;
- to point out the influence of friction conditions on the feasibility of the deep drawing process.

2. DEEP DRAWING TEST

Figure 1 shows the principle of deep drawing test. The blank is placed on the plane surface of the die, and then the blank holder is applied to the blank. The blank holder serves to prevent the wrinkles formation and to control the sliding of the blank in the die cavity during the drawing process. After application of the blank holder, the blank is formed by the punch through its axial displacement [6].

In the deep drawing process, the most severe friction occurs in the flange area. When the blank holder force (BHF) increases, the friction force at the interface blank holder - blank – die, increases. The friction conditions can therefore be assessed, by determination of the maximum applied blank holder force, without fracture of the specimen [7].

3. FINITE ELEMENT MODEL

In this study a finite element model for forming of a cylindrical cup of 52 mm diameter and 34 mm deep was build using the commercial available code eta/DYNAFORM (Fig. 2). Figure 1 shows the dimensions of the tools used in this study. The finite element model includes the specific elements of deep drawing test: the blank, the punch, the die and the blank holder. Both blank and tools were modeled as surfaces. The blank was modeled as a deformable and tools were modeled as rigid elements.

In order to study the effect of friction conditions on the punch force in the deep drawing test, three values of friction coefficient were used:

- $\mu = 0.25$ - dry friction conditions;
- $\mu = 0.14$ - normal conditions of friction;
- $\mu = 0.06$ - special conditions of friction.

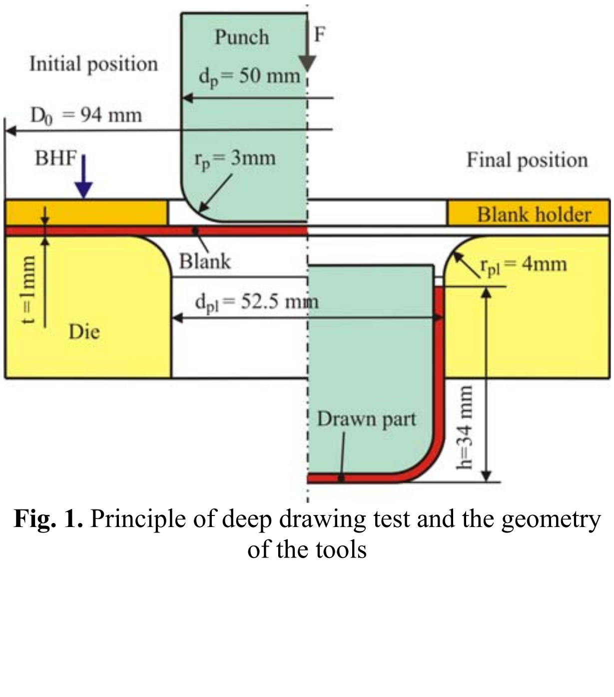

Fig. 1. Principle of deep drawing test and the geometry of the tools

Also, in order to study the influence of the blank holder force (BHF) on the punch force, three values of blank holder force were used, namely: 4 kN; 8 kN and 16 kN.

A DC06 low carbon steel with a thickness of 1 mm, mostly used for automotive components and body panels, and defined by the European normalization EN 10130 was chosen for the simulation. The DC06 steels show a low tensile strength combined with large elongation.

Table 1

Material properties of the blank

Parameter	Value
Young's modulus, E (MPa)	2.11×10^5
Yield stress, $R_{p0.2}$ (MPa)	123.6
Mass density, ρ (Kg/m^3)	7850
Poisson's ratio, ν	0.3
Strength coefficient, K (MPa)	529.5
Hardening exponent, n	0.268
Initial plastic strain ε_0 (-)	0.00438

4. RESULTS

Figures 3-5 show the relationship between punch force and punch displacement for different values of friction coefficient, in the case of the three values of blank holder force. In all three figures can bee clearly observed the influence of friction conditions on the punch force. The curve "punch force vs. punch displacement" is translated to higher values of the punch force with increasing of friction coefficient.

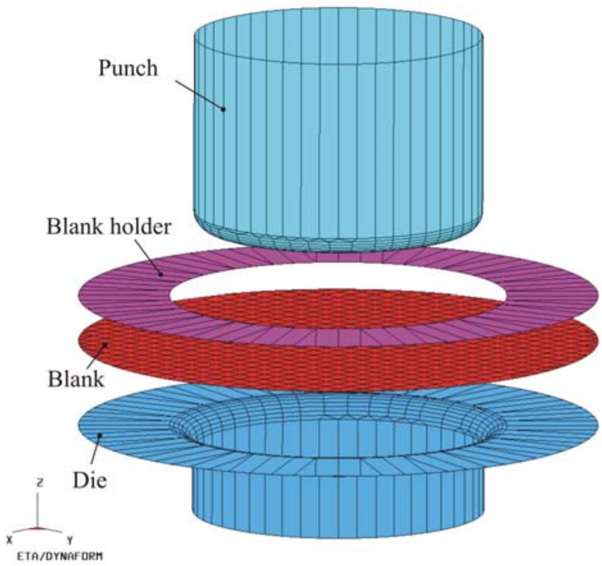

Fig. 2. Tools and blank used in the FE-Simulation

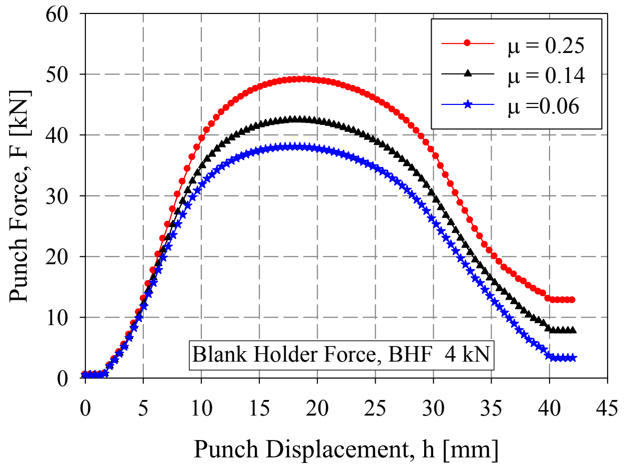

Fig. 3. Punch force vs. punch displacement in the case of BHF = 4 kN

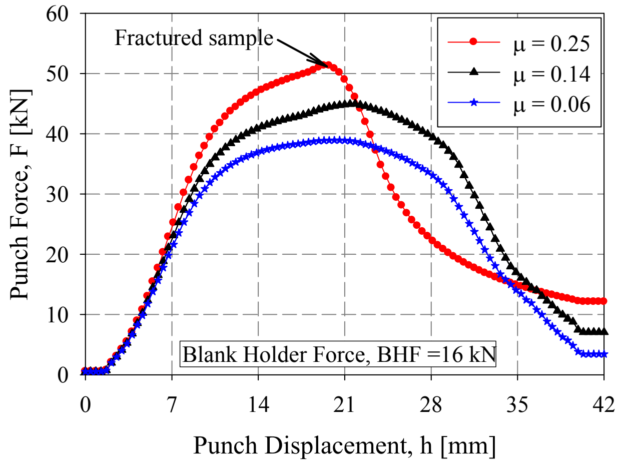

Fig. 5. Punch force vs. punch displacement in the case of BHF = 16 kN

The most important deformation of the material, in the deep drawing, is in the flange area of the blank. The required drawing force is equal to the force able to produce this deformation at which will added the bending force and friction force between blank and die shoulder.

It should be noted that the shape of the curves "punch force vs. punch displacement" obtained in this study (Figs. 3-5) are in good agreement with the literature [8], namely: when the drawing conditions are optimal, the maximum punch force is located at the beginning of the punch displacement, and in the case of unfavorable conditions caused by excessive friction, by clearance between punch and die or by the to higher blank holder force, then the maximum punch force is recorded towards the end of the punch stroke.

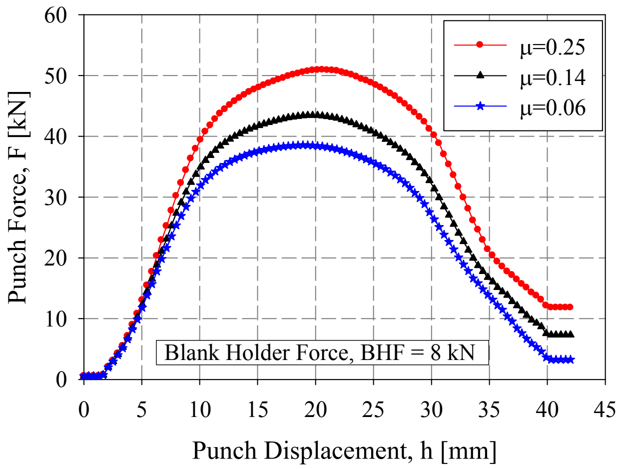

Fig. 4. Punch force vs. punch displacement in the case of BHF = 8 kN

As noticeable from Figures 3-5, in the case of friction coefficient μ = 0.06, the maximum punch force occurs in the first part of the punch stroke, in the zone where the center of the punch radius pass the center of the die radius.

From Figure 5, where the blank holder force had the highest value in this study (BHF = 16 kN), can be see that by increasing of the friction coefficient, the maximum value of punch force moves towards the end of the punch stroke, reaching in the case of μ = 0.25 to be even at the end of the punch displacement. In this case the fracture occurs before the complete drawing of the blank.

Figure 6 shows the influence of friction coefficient on the maximum punch force for different values of the blank holder force. The increasing of blank holder force determines the increases of the contact pressure between blank and tools in the flange area, leading to an increase of the friction force and, implicit to the increasing of the punch force.

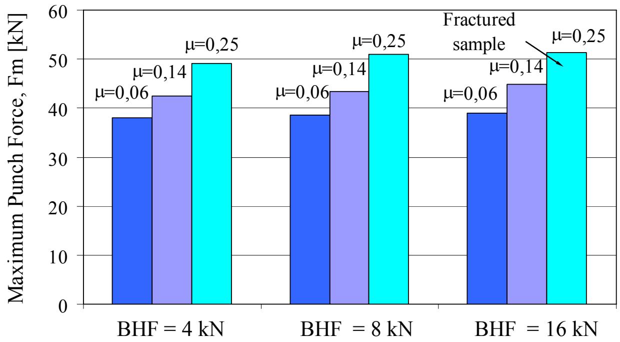

Fig. 6. Effect of friction coefficient on the maximum punch force

5. CONCLUSION

As results of the deep drawing test analysis, using finite element simulations, it was found that the friction between blank and tools has a significant influence on the punch force. The punch force increases with increasing of friction coefficient between the blank and tools. An important role regarding the influence of friction condition on the punch force has also the blank holder force. By increasing of blank holder force, increases the contact pressure at the interface plank-tools in the flange area, leading to an increase of friction force in this area and therefore to the increasing of punch force.

6. REFERENCES

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SIMULAREA CU ELEMENTE FINITE ŞI ANALIZA CONDIŢIILOR DE FRECARE ÎN ÎNCERCAREA LA AMBUTISARE

Rezumat

In această lucrare este prezentată o analiză privind influenţa condiţiilor de frecare asupra forţei poansonului şi a fezabilităţii procesului în cadrul încercării la ambutisare adâncă a unei piese cilindrice. Pentru aceasta a fost realizat un model de simulare cu elemente finite a încercării la ambutisare adâncă. Parametri variaţi în cadrul acestui studiu au fost coeficientul de frecare dintre scule şi semifabricat şi forţa de reţinere a semifabricatului. În urma analizei încercării la ambutisare, cu ajutorul simulărilor numerice, s-a constatat faptul că frecarea dintre semifabricat şi scule are o influenţă semnificativă asupra forţei poansonului. Forţa poansonului creşte cu creşterea frecării dintre semifabricat şi scule. Un rol important privind influenţa frecării asupra forţei poansonului îl are şi forţa de reţinere a semifabricatului. Prin creşterea forţei de reţinere, creşte presiunea de contact la interfaţa semifabricat-scule în zona flanşei, ceea ce conduce la creşterea frecării în această zonă şi implicit la creşterea forţei poansonului.

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