TECHNICAL UNIVERSITY OF CLUJ-NAPOCA

ACTA TECHNICA NAPOCENSIS

Series: Applied Mathematics, Mechanics, and Engineering
Vol. 65, Issue IV, November, 2022

NUMERICAL STUDY ON THE INFLUENCE OF FRICTION CONDITIONS ON THE PARAMETERS OF THE DIRECT EXTRUSION PROCESS

Mariana POP, Dan FRUNZĂ

Abstract: *The aim of this work is to present the result of a numerical study using Forge software, regarding the influence of friction conditions from plastic deformation processes on their technological parameters. The paper presents the influence of friction between the semi-finished product and the die in the case of direct cold extrusion. The material used in the simulation was lead, the lubrication conditions were without lubricant and mineral oil, the angles of the dies were 300 and 900. Conclusions were drawn regarding the influence of friction on the temperature of the semi-finished product, the energy stored by friction, the deformation force.*

Key words: *friction, extrusion, simulation, die, force*

1. INTRODUCTION

Deformation of metals is achieved by plastic deformation of the shape of a solid body, preserving both mass and adhesion. Metals deformation processes can be classified into several groups, such as deformation mechanism (tensile, compression, shear bending), time dependence (independent and time-dependent processes like extrusion and upsetting), or the deformation temperature (cold, hot deformation) [1,2,3].

Hot deformation has advantages of higher formability and recrystallization which makes the metal easier to deform, while in cold deformation it is possible to increase the strength of the product. Cold forming can also allow greater geometric accuracy and surface finish by avoiding thermal problems such as oxidation.

2. THEORETICAL ASPECTS

The definition of friction, can be "resistance of the surface to relative sliding" but in metal forming this term is transformed into "the strength of workpiece-die surface to material flow" [3,4,5].

In the plastic deformation processes of metals, materials in general friction is a complex phenomenon and includes parameters that interact such as: sliding speed, contact pressure, surface roughness, properties of the material, material temperature, type of lubrication [1,2,3,4,6].

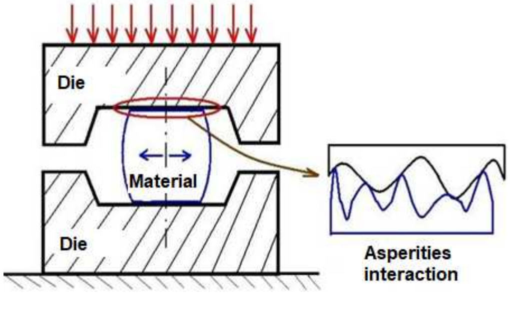

Fig. 1 The interaction of asperities die - workpiece [1]

Friction has a significant role in metal forming. Allows determination of tools life, material formability and the quality of finished product. Excessive friction leads to phenomena like heat generation, wear and increased the temperature of tool surface. Also friction can increase deformation inhomogeneity, which

Received: 04.08.22; **Similarities**: 19.10.22: **Reviewed**: 26.10./01.11.22: **Accepted**:17.11.22.

will lead to the appearance of defects in final products [3].

Therefore, different lubricants are used to reduce friction during metal deformation [2]. It is not always practical to reduce friction to a very low value.

In finite element simulations, the friction model is one of the key input conditions. It is also difficult to establish a single friction model that includes all deformation parameters specific to all deformation processes. The Coulomb and Tresca models exist in commercial finite element analysis (FEA) packages. The friction coefficients for the main deformation processes are presented in table 1 [1]. During the plastic deformation of metallic materials, sliding friction usually occurs on the contact surfaces between the body subject to deformation and the deformation tools, which is very different from the sliding friction that occurs in machine parts. Also in the case of machine parts, the variation of the surfaces on which the friction occurs is practically negligible and is usually due only to wear. In the case of plastic deformation, however, the contact surfaces between the body and the deformation tools change continuously throughout the deformation process, according to the law of minimum resistance.

There are four basic types of lubrication that determine the frictional conditions in metal forming. The Stribeck curve shown in figure 2 illustrates the occurrence of these different types of lubrication as a function of the combination of lubricant viscosity η, sliding speed v and normal pressure p [7].

Table 1 [1]

Friction coefficient for different processes

Process	**Friction coefficient, μ**	
	Cold	**Hot**
Rolling	0,05 – 0,1	0,2 – 0,7
Close die forging	0,05 – 0,1	0,1 – 0,2
Drawing	0,03 – 0,1	–
Deep drawing	0,05 – 0,1	0,1 – 0,2

The main types of lubrication are:

1. In dry conditions. There is no lubricant at the interface tool-material and only the oxide layers is present. In this case, friction is high and this situation is desirable hot rolling of plates and sheets and unlubricated extrusion of aluminum alloys [7].

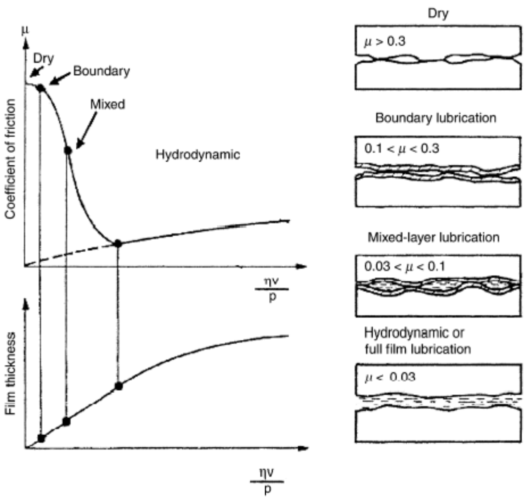

Fig. 2 Stribeck curve showing onset of various lubrication mechanisms [7]

2. Boundary lubrication. In this case thin films (usually organic) is physically adsorbed or chemically adhered to the metal surface. Like in dry conditions, friction is high [7].

3. Full film lubrication. It exists when there is a thick layer of solid lubricant/dry coating between the dies and the workpiece [7].

4. Hydrodynamic conditions. It exists when a layer of lubricant is present between the tool and the workpiece. In this case, the friction conditions are determined by the viscosity of the lubricant and the relative speed between the tool and the workpiece. As indicated by the Stribeck curve, friction is relatively low [7].

5.Lubrication with mixed layer is the most common situation in metal deformation. In the majority of metal forming operations, hydrodynamic conditions cannot be maintained. Many liquid lubricants contain organic substances that will adsorb or chemically react with the metal surface to create a barrier against the contact between metals. The friction is moderate in this case [7].

3. SIMULATION CONDITIONS

With the help of the software FORGE, the direct extrusion process of a semi-finished product was simulated, with the aim of determine the influence of the friction coefficient on the parameters of the deformation process. The extrusion simulation was carried out on dies with an angle of 30° and 90°, in the unlubricated state, respectively lubricated with mineral oil [8].

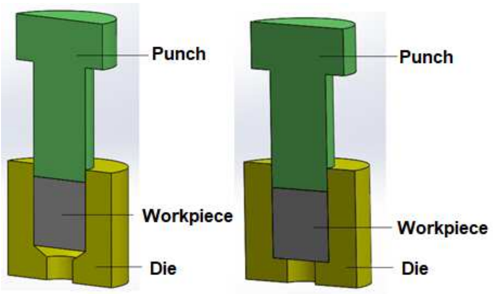

Fig. 3 The die-punch-workpiece assembly

The punch, workpiece and dies were modeled in SOLIDWORKS and the dimensions of each part are shown in figure 4.

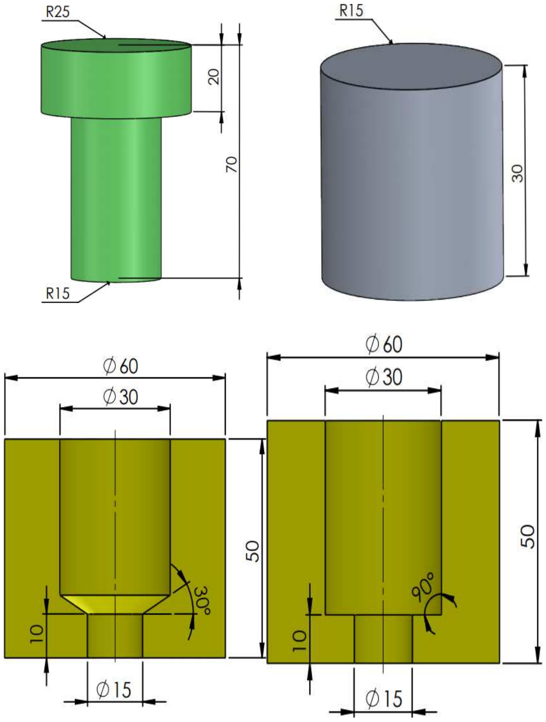

Fig. 4 Dimensions of the punch, the workpiece and the dies with the angle of 30° and 90°

The geometrical models were imported into the FORGE software, so that were discretized and the contact between the tools and the workpiece product was correct. In the preprocessor, the material of the workpiece, the coefficient of friction, the temperature of the material and tools, the heat transfer and the characteristics of the deformation equipment were defined. The postprocessor displays the results (strains, stresses, temperatures, forces, material flow, etc.). In the deformation process, the die is considered fixed, and the punch is mobile and performs the deformation of the semi-finished product. The parameters of the deformation process (direct extrusion) are presented in Table 2. The rheological module of the software uses a type of Hansel-Spittel evolution.

$$\sigma = A\dot{\varepsilon}^{m_1 T} T^{m_9} \varepsilon^{m_2} \dot{\varepsilon}^{\frac{m_4}{\varepsilon}} (1+\varepsilon)^{m_5 T} \dot{\varepsilon}^{m_7 \varepsilon} \varepsilon^{m_3} \varepsilon^{m_8 T}$$

Table 2

Simulation conditions

Material	Lead
Workpiece height [mm]	30
Workpiece diameter [mm]	30
Workpiece temperature [°C]	20
Die temperature [°C]	20
Punch speed [mm/s]	0,5
coefficient of friction non-lubricated surface [-]	0,3
coefficient of friction lubricated surface [-]	0,1

4.SIMULATION RESULTS

a) Simulation of the extrusion process with a die angle of 30°, without lubrication

Figure 5 shows the temperature variation during the extrusion process. The temperature of the workpiece rises in the deformation zone, because there the phenomenon of friction occurs and the deformation energy is transformed into heat, that increse the material temperature.

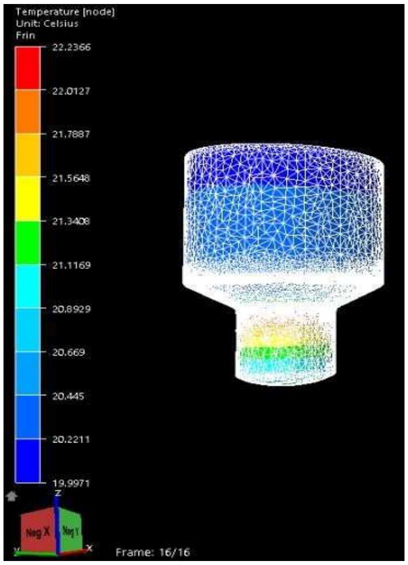

Fig. 5 Temperature variation during the process

Figure 6 shows the temperature evolution during the process as a function of the stroke of the punch. The temperature gradually increases as the punch pushes the workpiece into the die.

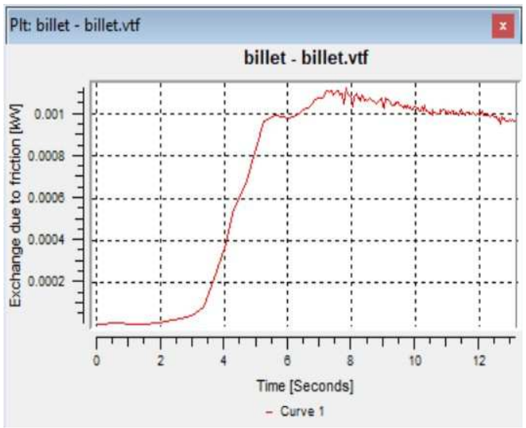

Fig. 6 Temperature evolution during the process

The energy accumulated by friction in the workpiece during the extrusion process is presented in figure 7.

Figure 8 shows the variation of the extrusion force acting on the surface of the semi-finished product. At the moment the punch touches the workpiece, the force begins to gradually increase up to 15 kN, it remains at the same value until the material is deformed, after which it relaxes and decreases.

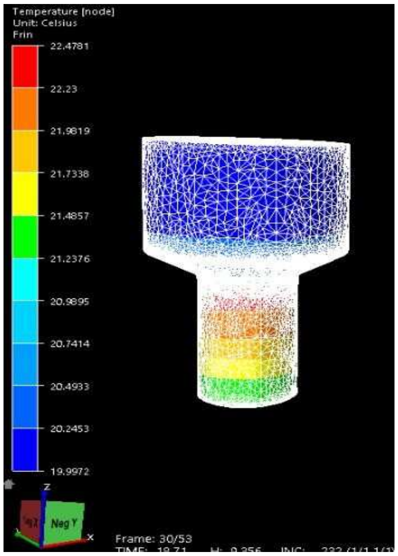

Fig. 7 The energy accumulated by friction in the workpiece during the process

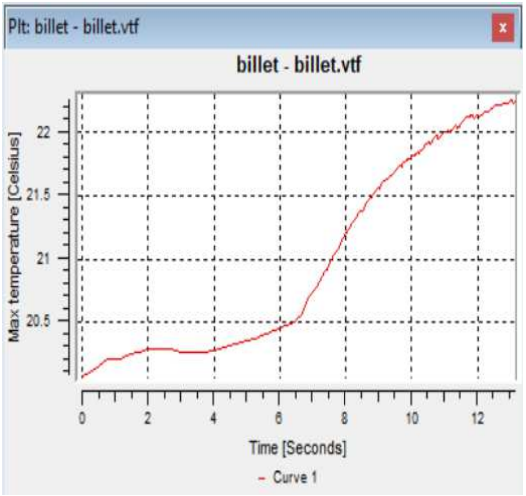

Fig. 8 Variation of the deformation force during the process

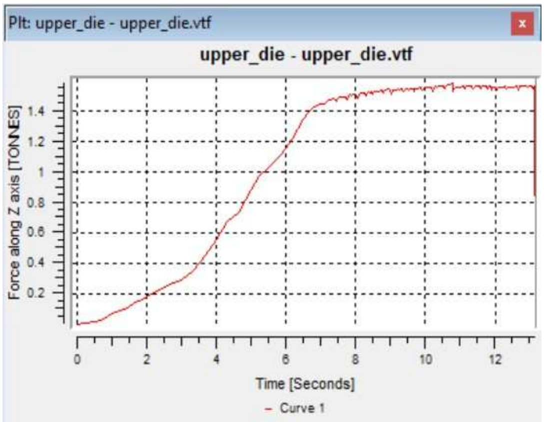

Fig. 9 Temperature variation during the process

b) Simulation of extrusion process with 30° die angle, lubricated with mineral oil

In figure 9, the temperature variation of the extrusion process in the state lubricated with mineral oil is shown. The temperature does not rise as much as in the unlubricated extrusion process, because mineral oil is present on the surface which reduces friction and thus the material does not heat up.

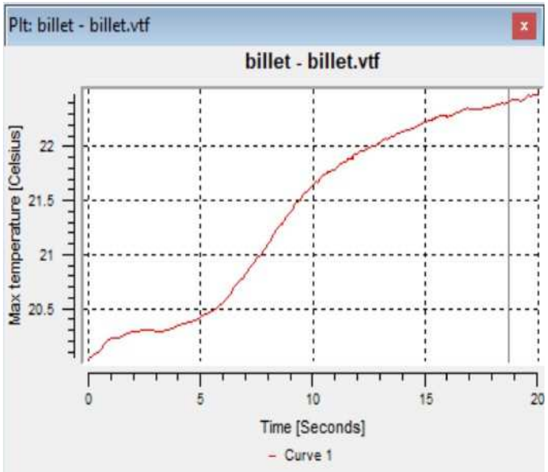

Fig. 10 Temperature evolution during the process

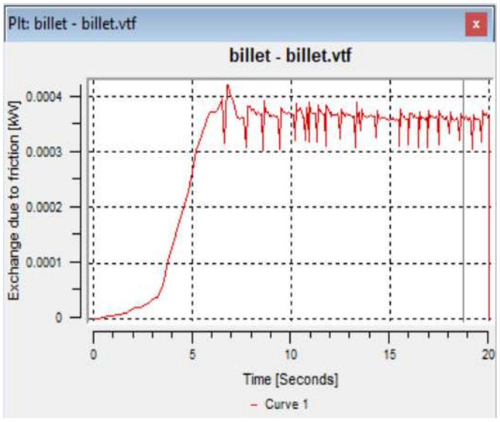

Fig. 11 The energy accumulated by friction in the workpiece during the process

The energy increases but not as much as in the case of no lubrication. Here the maximum value is 0.0004 kW, much lower than in the unlubricated extrusion process, due to the presence of mineral oil lubrication.

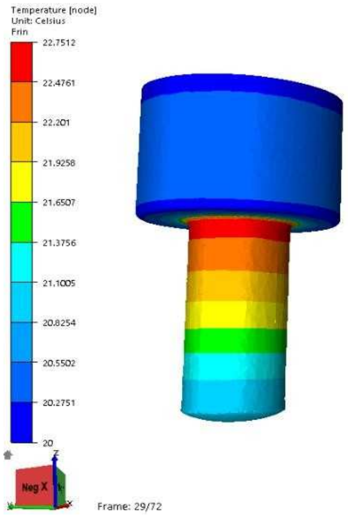

Fig. 12 Variation of the deformation force during the process

c) Simulation of the extrusion process with the die angle of 90 °, without lubricantion

Fig. 13 Temperature evolution during the process

Fig. 14 The energy accumulated by friction in the workpiece during the process

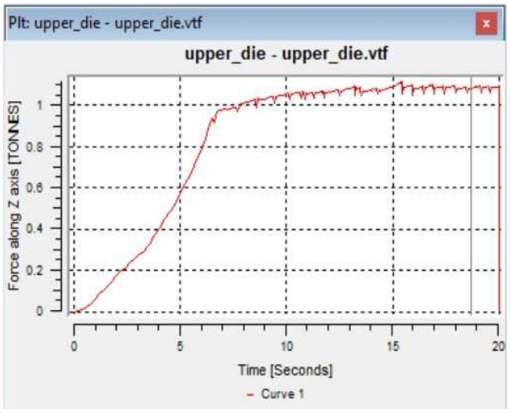

Fig. 15 Variation of the deformation force during the process

d) Simulation of extrusion process with 90° die angle, mineral oil lubrication

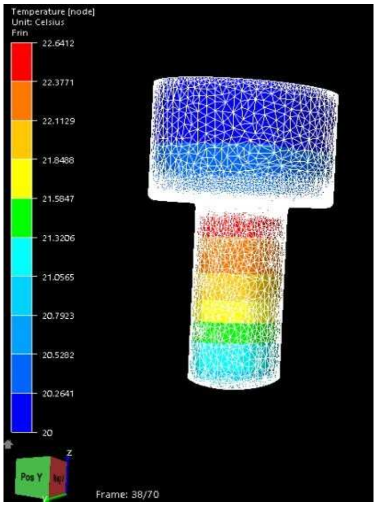

Fig. 16 Temperature variation during the proces

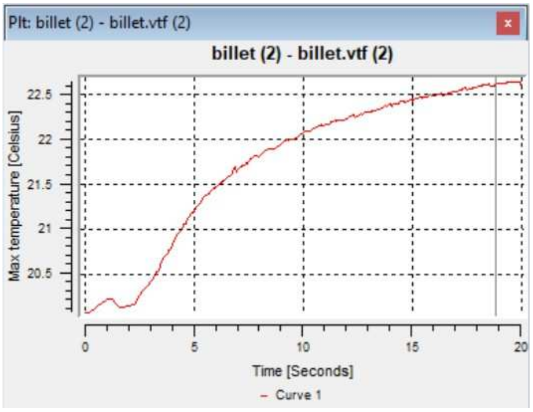

Fig. 17 Temperature evolution during the process

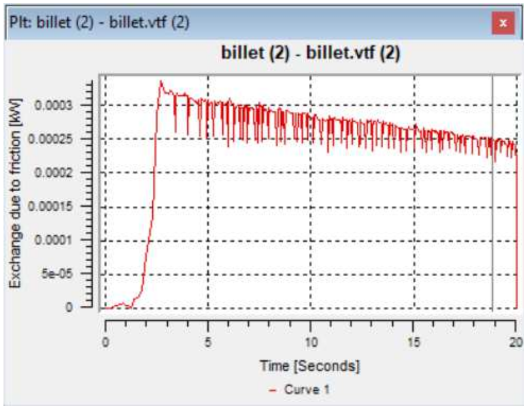

Fig. 18 The energy accumulated by friction in the workpiece during the process

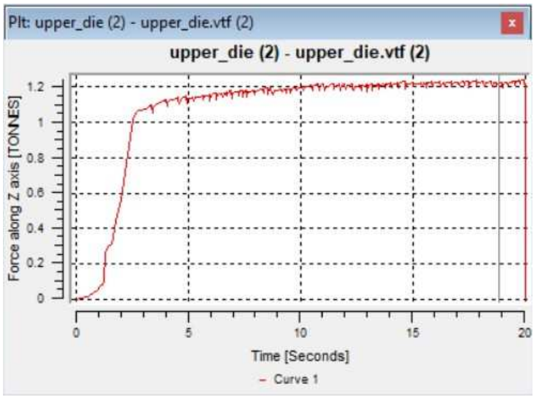

Fig. 19 Variation of the deformation force during the process

The force increases rapidly when the deformation starts, being constant at 12 kN throughout the deformation. Its value is lower than in the 90° die extrusion process in the unlubricated state , because there is lubricant and the material flows better.

5.CONCLUSIONS

The bibliographic study, show the importance of the phenomenon of friction the plastic deformation processes of materials.

Friction influences the parameters of these processes: deformation forces, strains, stresses, temperatures, etc.

The simulation of the direct extrusion process under different deformation conditions and on dies with different deformation angle was carried out to highlight the temperature, energy consumed by friction, deformation force in the workpiece during deformation. It can be seen that in the extrusion process with the die angle of 30° the material flow is more favorable.

The force applied to the deformation is lower due to the angle which makes possible an easier flow of the blank through the die, both in the lubricated and unlubricated state. However, the presence of a lubricant on the surface reduces the friction and the temperature of the blank in the calibration area, leading to a homogeneous deformation.

In the case of the 90° angle, the flow of the material is unfavorable. The force required for deformation is higher due to the angle which makes it harder for the workpiece to deform.

The mineral oil used as a lubricant reduces the friction between the workpiece and the die, but it is not as reduced as in the case of 30° angle extrusion.

Due to the right angle, the material tends to flow towards the center, and the dead zone is formed in the corners, which is not 54

So, in order not to encounter problems when extruding materials, angled dies and different lubricants will be used as much as possible to have better flow and reduce friction.

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Studiu numeric privind influența condiților de frecare asupra parametrilor procesului de extrudere directa

Rezumat: Scopul acestei lucrări este de a prezenta rezultatul unui studiu numeric folosind software-ul Forge, privind influența condițiilor de frecare din procesele de deformare plastică asupra parametrilor tehnologici ai acestora. Lucrarea prezintă influența frecării dintre semifabricat și matriță în cazul extrudării directe la rece. Materialul folosit în simulare a fost plumb, condițiile de lubrifiere au fost fără lubrifiant și lubrefiere cu ulei mineral, unghiurile matrițelor au fost de 30^0 și 90^0. S-au tras concluzii cu privire la influența frecării asupra temperaturii semifabricatului, a energiei stocate prin frecare, forței de deformare.

Mariana POP, Associate Prof. Dr. Eng., Technical University of Cluj-Napoca, Department of Materials Science and Engineering, 103-105 Muncii Blvd, 400641 Cluj-Napoca, Romania, E-mail: mariana.pop@ipm.utcluj.ro, , Phone: 0040 264 401 628

Dan FRUNZA, Associate Prof. Dr. Eng., Technical University of Cluj-Napoca, Department of Materials Science and Engineering, 103-105 Muncii Blvd, 400641 Cluj-Napoca, Romania, E-mail: dan.frunza@ipm.utcluj.ro, Phone: 0040 264 401 6