Available online at www.sciencedirect.com

ScienceDirect

Procedia Technology 22 (2016) 34 – 39

Procedia Technology

9th International Conference Interdisciplinarity in Engineering, INTER-ENG 2015, 8-9 October 2015, Tirgu-Mures, Romania

Finite Element Analysis of Drawing Wire in Cassette Roller Die (Part 2)

Adriana-Maria Mihu[a,]*, Ioana Monica Sas-Boca[a], Ionut Marian[a], Iulian Sebastian Mihu[a], Dorina Simona Ianc[a], Liviu Nistor[a], Dana-Adriana Ilutiu-Varvara[a]

[a]*Technical University of Cluj-Napoca, 28 Memorandumului Street, 400114, Cluj-Napoca, Romania*

Abstract

A complex study of the drawing process with cassette roller die, of the round wires is presented through 3D finite element simulations. The geometrical model is used for the wire and also for the device. The results of the numerical simulations are being compared with the theoretical analysis previously performed.
This paper presents and analyses the influence of the variation process parameters such as: friction coefficient, radius of the working rollers, also initial and final diameter of the billet in the drawing process with cassette roller die.
The comparison between drawing forces according to the stroke of wire drawing-in implement to different parameters values, concord in a numerical model predictions, thus validating the theoretical analysis.

Peer-review under responsibility of the “Petru Maior” University of Tirgu Mures, Faculty of Engineering

Keywords: cassette roller die; drawing; wire; optimization; simulation.

1. Introduction

Reducing manufacturing costs and meeting quality requirements so all the pieces obtained by plastic deformation, imposed new approaches to design technology and working tools, all of these market requirements are replacing the

* Corresponding author. Tel.: +40-741-627-744.
E-mail address: mihu_adriana_maria@yahoo.com

Peer-review under responsibility of the “Petru Maior” University of Tirgu Mures, Faculty of Engineering
doi:10.1016/j.protcy.2016.01.006

repeated attempts to finalize the technological solutions currently practiced in the areas of plastic deformation [1,2,3,4].

The method that best responds to these requirements is the finite element analysis (FEA) [5,6,7,8].

The simulation of wires drawing process in cassette roller die, allows the optimization of the shape and properties of working rolls [9], before they are made. As a result, redesign costs can be avoided.

Nomenclature

D_i, dsi	initial diameter of billet
D_f, dsf	final diameter of billet
R	rollers working radius
μ	friction coefficient

The drawing process efficiency depends significantly on appropriate selection of a large number of parameters such as: process, material and die. The conditions of drawing (section reduction, stress, etc.), the properties of the deformed material (tensile strength, yield strength, microstructure, etc.) and the breaking behavior (ductile fracture, sliding grain, etc.) are interrelated [10].

Multiple drawing requires the consideration of several process parameters [11,12,13]. These parameters affect the stresses and strain developed in the wire material, affecting both energy consumption and the location of non-uniformity strains and wire breakage, including that of the productivity drawing equipment.

Thus, it is necessary to develop an optimized technique to process multiple drawing, and suggest working arrangements with the optimal succession of reductions. This leads to increased productivity, high product quality and also reduced manufacturing costs.

The aim of this paper is the FEA of drawing wire with cassette roller die.

2. Material and method

The 3D finite element simulations on this study are made on the basis of the theoretical calculations from Part 1 (The influence of process parameters on non-conventional technology in drawing cassette roller die).

In order to optimize parameters we followed: the coefficient of friction, the radius of work rolls, the initial diameter of the wire (and the oval profile cross section of the roll), and the final diameter of the wire (and the rounded profile cross-section of the roller).

The analyzed values for friction coefficient are: $\mu = 0.05$; $\mu = 0.10$; $\mu = 0.20$; $\mu = 0.30$. The constant parameters of this study are: the initial diameter of the billet, $D_i = 5.0$ mm; the final diameter of the billet, $D_f = 4.0$ mm; and the working rollers radius, R = 100 mm. Since the dimensions of the billet, both before and after the forming, are constant, the roll profile cross section is constant for both rollers (oval and round).

The rollers working radius values studied is: R = 50 mm; R = 75 mm; R = 100 mm; R = 125 mm. The constant parameters of this study are: the initial diameter of the billet, $D_i = 5.0$ mm; the final diameter of the billet, $D_f = 4.0$ mm; the oval and the rounded profile cross-section of the roller and the friction coefficient, $\mu = 0.30$.

The values for the initial diameter of the wire, involved in the analyzed process, where: $D_i = 4.6$ mm; $D_i = 4.8$ mm; $D_i = 5.0$ mm; $D_i = 5.2$ mm. From the calculations above it is clear that, for proper functioning of the device, the variation of the initial diameter of the billet, must vary the surface of the cross-section of the groove of the roll of oval. The constant parameters of this study are: the final diameter of the billet, $D_f = 4.0$ mm (and the rounded profile cross-section of the roller); the working rollers radius, R = 100 mm and the friction coefficient, $\mu = 0.30$.

For the final diameter of the wire, the values were analyzed: $D_f = 3.6$ mm; $D_f = 3.8$ mm; $D_f = 4.0$ mm; $D_f = 4.2$ mm. The constant parameters of this study are: the initial diameter of the billet, $D_i = 5.0$ mm (and the oval profile cross-section of the roller); the working rollers radius, R = 100 mm and the friction coefficient, $\mu = 0.30$.

The measurements were performed on the electrolytic copper wires with 99,5 % purity.

The experimental assembly was modeled using SolidWorks software, and we used: billet, wire drawing-in implement, rolls with oval groove, rolls with round groove and support (Fig. 1a).

This study was performed using finite element analysis software, FORGE 2009-FEA. The reason for our choice is that software, allows the use of symmetry and to reduce computation time, and also it used a simplified version of wire drawing device, so it's only got 1/4 of billet, only 1/2 of the work rolls and support to quit (Fig. 1b).

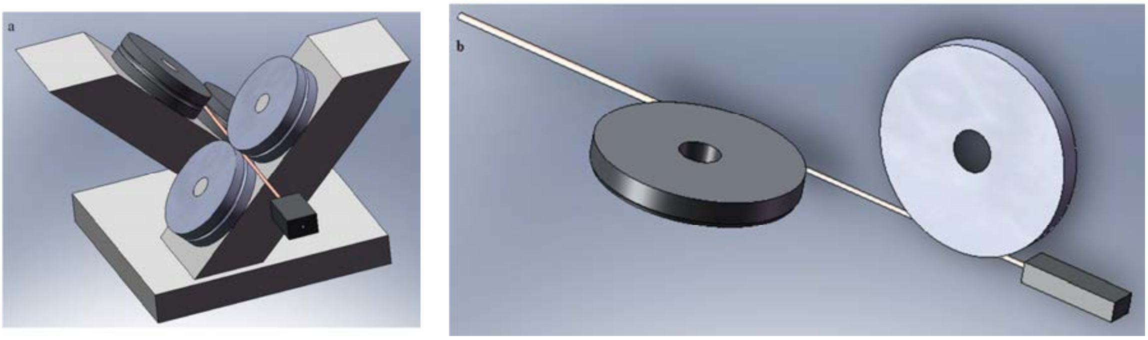


Fig. 1. (a) The device wire drawing in cassette roller die; (b) The device used for simulation.

3. Results and discussions

The variation of friction coefficient (Table 1a) shows the necessity that processing rollers have different roughness, because the best filling on oval section occurs when the friction coefficient (μ) is 0.05, and on round section, when this is 0.20.

From the pictures we can easily observe that the deformation does not occur over the entire surface of the wire, being limited to the contact with the rollers, so that the caliber of oval, the deformations taking place in the vertical direction, and the round in the horizontal direction.

From the Fig. 2a we can observe that the drawing force is less influenced by the friction coefficient, the studied values are very close. However, it can be said that with increasing friction coefficient, increases drawing force.

Table 1b is revealing that, if the roll radius R = 100 mm, there is a uniform filling of the deformation profile. The cross-sectional deformation decreases with the increase of the radius of the rollers, and at the contact wire - roll this due to the increase of grip angle.

From the Fig. 2b we can observed that drawing force is inversely proportional to the radius of work rolls, influential factor remaining the grip angle (small for roller with R=50, great for R=125). An optimal value in this case would be approach 0.17 kN.

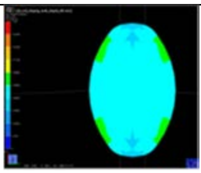
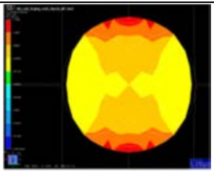
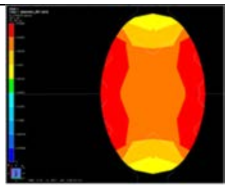
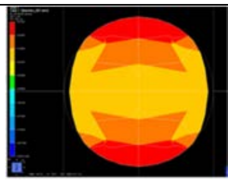
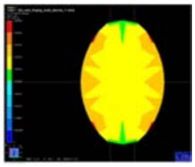
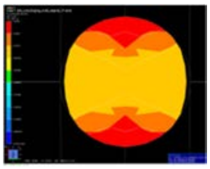
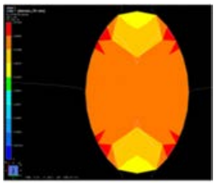
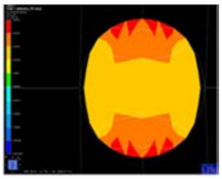
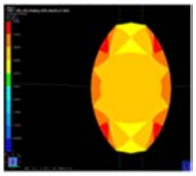
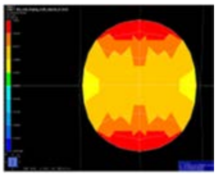
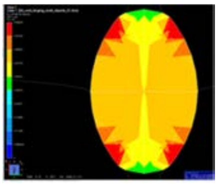
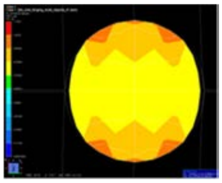
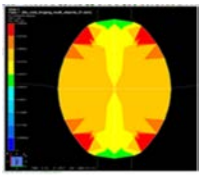
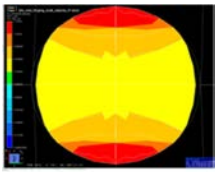
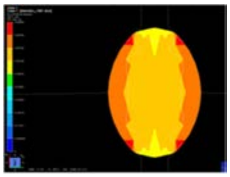
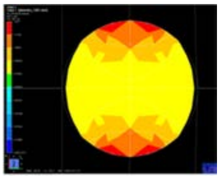
From Table 2a it is apparent that the initial diameter of the wire, D_i = 5.2 mm, best fill the deformation profile, both on the oval, and in round one. Hence, it is apparent that this process is suitable for an initial diameter of 5.2 mm to obtain wire with the final diameter, D_f = 4 mm.

The Fig. 3a reveals that the drawing force increases in ratio with the initial diameter of the wire increasing. This is because a higher initial diameter means a greater quantity of material, in the cross section of the wire, to be deformed.

At constant initial diameter (Table 2b) we can observed that with increasing of the round groove (D_f > 3.8 mm), decreases the filling degree of the profile, and the decrease of the groove (D_f < 3.8 mm) so the deformed material flows into burr.

As in the case of the initial diameter of the wire, with the increase of the final diameter of wire, the drawing force increases (Fig. 3b), also because of the increase of the quantity of material to be deformed in cross-section.

Table 1. The evolution of deformations on cross-section of the billet, for μ and R.

a. For different friction coefficient			b. For different working roller radius		
Friction coefficient, μ	Section with oval profile	Section with round profile	Working roller radius, R [mm]	Section with oval profile	Section with round profile
0,05			50		
0,10			75		
0,20			100		
0,30			125		

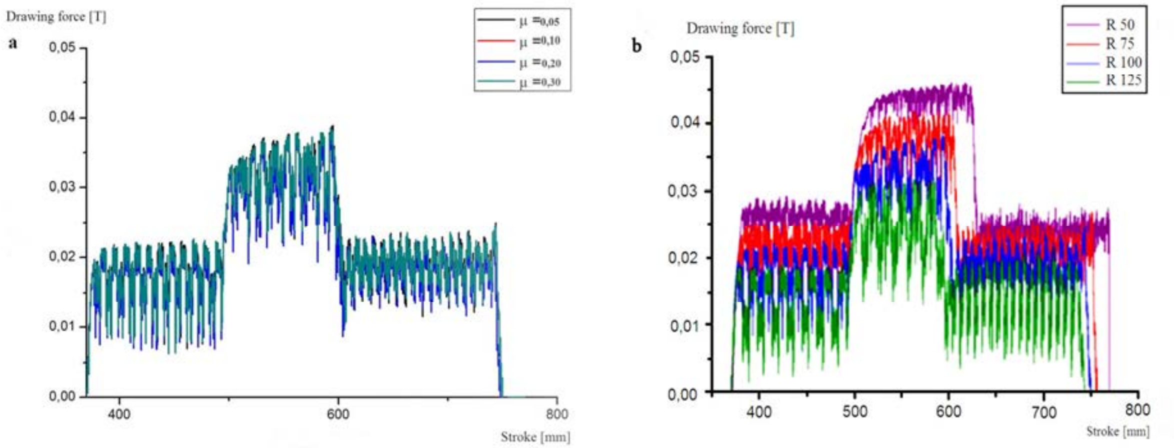
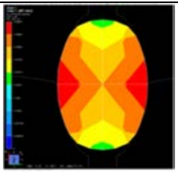
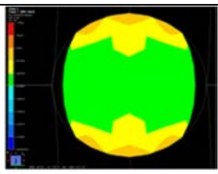
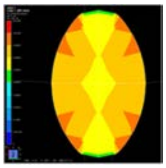
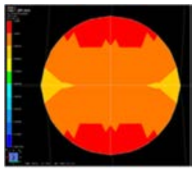
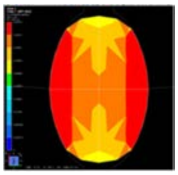
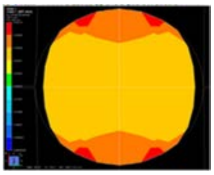
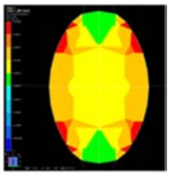
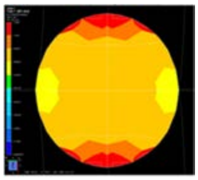
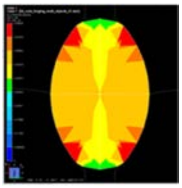
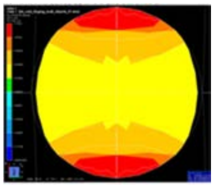
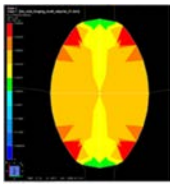
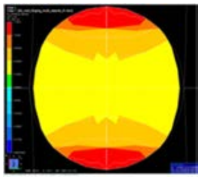
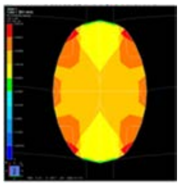
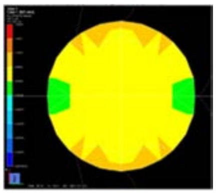
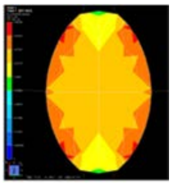
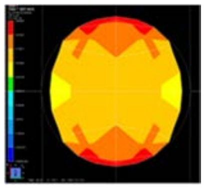


Fig. 2. The drawing force evolution in ratio with: (a) μ and (b) R.

Table 2. The evolution of the deformations on cross-section of the billet, for D_i and D_f.

a. For different initial diameter of the wire			b. For different final diameter of the wire		
Initial diameter of the wire, D_i [mm]	Section with oval profile	Section with round profile	Final diameter of the wire, D_f [mm]	Section with oval profile	Section with round profile
4.6			3.6		
4.8			3.8		
5.0			4.0		
5.2			4.2		

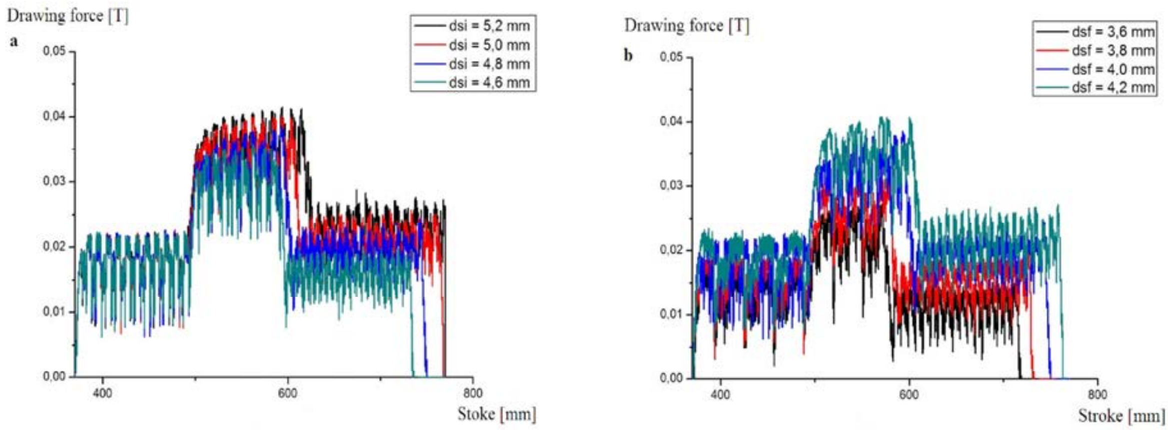


Fig. 3. The drawing force evolution in ratio with: (a) dsi and (b) dsf.

4. Conclusions

Based on this study reached the following conclusions:

- the drawing force is directly proportional to the coefficient of friction and the dimensions of the initial / final of the wire and inversely proportional to the radius of the work roll;
- the force required by the deformation process is the sum of forces required for each deforming gauge;
- the cross-section has low deformations in the middle of the wire, and higher levels of deformation of the surface. However, they will not occur on the entire surface of the wire, but only on the portions in contact with the rollers, oval profile in the vertical direction and the horizontal direction for round profile.
- optimum friction coefficient for round is 0.05 and for oval roll is 0.20, which means that the tools surface will be is processed with different roughness.
- optimal working rollers radius are R = 100 mm, and the deformation force is approach 0.36 kN. The results are comparable to those obtained in the theoretical calculations (Part 1).
- the optimum dimensions of the billet were initially 5.2 mm diameter of wire to obtain a final diameter of 4 mm diameter. Also, the optimum dimension of the billet was initially 5 mm for obtaining a 3.8 mm final diameter.

The comparison between drawing force according to the stroke of wire drawing-in implement to different friction coefficient ($\mu = 0.05$; $\mu = 0.10$; $\mu = 0.20$; $\mu = 0.30$), different working rollers radius (R = 50 mm; R = 75 mm; R = 100 mm; R = 125 mm) and different initial / final diameter of the wire concord in a numerical model predictions, thus validating the theoretical analysis.

References

[1] Milenin AA, Dyja H, Mróz S. Simulation of metal forming during multi-pass rolling of shape bars. Journal of Materials Processing Technology 2004; 153–154:108–114.
[2] Solod V, Kulagin R, Beygelzimer Y. A local approach to simulating bar forming in pass rolling. Journal of Materials Processing Technology 2007; 190: 23–25.
[3] Sergey L, Abdrakhman N, Andrey V, Irina V. New combined process "pressing-drawing" and impact on properties of deformable aluminum wire. Procedia Engineering 2014; 81: 1505 – 1510.
[4] Korchunov A, Gun G, Polyakova M. Recovery effect in drawing of steel bar for sizing. Procedia Engineering 2014; 81: 676 – 681.
[5] Brezeanu LC. Contact stresses: analysis by finite element method (FEM). Procedia Technology 2014; 12: 401-410.
[6] Cazacu R, Grama L. Steel truss optimization using genetic algorithms and FEA. Procedia Technology 2014: 12: 339 – 346.
[7] Brezeanu LC. Contact stresses between two cylindrical bodies: cylinder and cylindrical cavity with parallel axes – Part I: Theory and FEA 3D modelling. Procedia Technology 2015; 19: 169-176.
[8] Brezeanu LC. Contact stresses between two cylindrical bodies: cylinder and cylindrical cavity with parallel axes – Part II: 2D and 3D FEA comparative study. Procedia Technology 2015; 19: 177-184.
[9] Byon S M, Na D H, Leeb Y. Effect of roll gap adjustment on exit cross sectional shape in groove rolling - Experimental and FE analysis. Journal of Materials Processing Technology 2009; 209: 4465–4470.
[10] Hirt G, Senge S. Selected processes and modeling techniques for rolled products. Procedia Engineering 2014; 81: 18 – 27
[11] Liao S, Zhang L, Yuan S, Zhen Y, Guo S. Modeling and finite element analysis of rod and wire steel rolling process. Journal of University of Science and Technology Beijing 2008; 4:412.
[12] Lambiase F, Di Ilio A. A parametric study on residual stresses and loads in drawing process with idle rolls. Materials and Design 2011; 32: 4832–4838.
[13] Orak İM, Akgul B. Fast and simple computer aided internal electrical wiring project design & integration of calculations. Procedia Technology 2012; 1: 280 – 285.