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Procedia Technology 22 (2016) 28 – 33

Procedia Technology

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

The Influence of Process Parameters on Non-Conventional Technology in Drawing Cassette Roller Die (Part 1)

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Abstract

This paper presents a new approach to the influence of the process parameters on non-conventional technology for drawing in cassette roller die. This technology combines two conventional methods of plastic deformation. The rolling, in this method the wire is passed through the two pairs of roller and, the drawing, using the drawing force that exist at the exit of the wire between the rolls. In conclusion there are two forces involved in the process of plastic deformation: drawing force and rolling force.

It has been shown that these forces are strongly influenced by variation of certain process parameters such as: the initial diameter of the sample, the elongation coefficient, the contact surface roll/sample, the average pressure of rolling, the friction coefficient and the rollers working radius.

The results depicts a helpful insight into the effects of the process parameters in the wire drawing with cassette roller die, thus furnishing the basic guidelines for process design and optimization.

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

Keywords: cassette roller die; drawing; wire; non-conventional technology; optimization.

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Peer-review under responsibility of the “Petru Maior” University of Tirgu Mures, Faculty of Engineering
doi:10.1016/j.protcy.2016.01.005

1. Introduction

The world economy, and the market itself, impose higher requirements every year. Achieving those requirements imposed high quality and efficient productivity in terms of conservation and environmental protection. All of these market changes led to the development of new technologies and new processes. Among all these new developing technologies, an important role is occupied by the non-conventional technologies of the plastic deformation of materials [1,2] which are required, due to technical and economic advantages [3,4,5].

The advantages are revealed in the following elements: increased productivity; material use factor; high diversity of finished and semi-finished products; variety of sizes and shapes; accuracy of dimensions; high quality of the surfaces; improved physical and mechanical properties of the materials; low energy consumption while preserving the environment etc. [6].

Nomenclature

b_m	average width of the sample
D_i	initial diameter of sample
F_F	drawing force
h_0	sample height before deformation
h_1	sample height after deformation
h_n	height neutral plane
l_c	contact arc length
n_σ	drawing force coefficient of tension stress
P	rolling force
p_m	average pressure of rolling
R	rollers working radius
S_c	contact surface roll/sample
Δh	absolute reduction
δ	coefficient
λ	elongation coefficient
μ	friction coefficient
σ_s	flow stress
$2k$	rolling resistance

Manufacturing wire by drawing in cassette roller die, is a plastic deformation non-conventional technology. This combines two conventional methods of plastic deformation: rolling [7], the wire is passed through the two pairs of roller, and drawing [8], due to the presence of a drawing force [9] located at the exit of the wire between the rolls (Fig. 1).

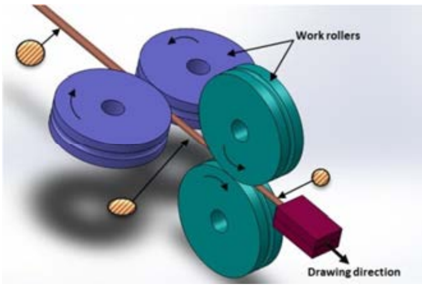

Fig. 1. The wire drawing in cassette roller dies.

The proposed technology aims to reduce or even eliminate some drawbacks of traditional methods. The list of processes that need improving is: the use of a large number of annealing; or a large number of drawing, also increasing the slow drawing speed; improve the reduced plasticity of the final product; the small degree of reduction; and the low productivity in general that affects the final product characterized usually by the irregularities of mechanical characteristics on wire length.

With this technology, the deformations occur simultaneously both directions: lateral and longitudinal; this lowers internal tensions and leads to uniform material flow on drawing direction. This process reduces the number of micro-cracks and surface defects [10].

The aim of this process is to achieve a lower cost price of the wire in terms of ensuring a higher quality of finished product.

In the specialized literature there are few references [10,11] about the parameters analyzed in this paper.

The brought novelty is that, in this study, we analyzed the forces according to the elongation coefficient, compared to references [11], which analyzed these forces according to thickness reduction and initial diameter of wire.

Compared to references [11] that analyzed a roller plane drawing device, with one pair of rollers, we analyzed a profiled roller device with two pairs of rollers.

2. Material and method

Two forces are involved in the wire drawing in cassette roller die: the rolling force, due to the presence of unguided rolls, and the drawing force required process development.

In this paper we analyzed the influence of process parameters variation on rolling and drawing forces: initial diameter of sample, elongation coefficient, contact surface roll/sample, average pressure of rolling, friction coefficient and rollers working radius.

Measurements were performed on the electrolytic copper wires of 99.5 % purity.

To analyze the influence of process parameters were chosen nine different elongation coefficients (nine initial sample) to get the same final sample with D_f = 4 mm. The values were chosen for elongation coefficient is: λ = 1.10; λ = 1.12; λ = 1.15; λ = 1.18; λ = 1.20; λ = 1.22; λ = 1.25; λ = 1.28 and λ = 1.30. Thus, we obtained nine initial diameter of sample, they are: D_i = 4,401 mm; D_i = 4,481 mm; D_i = 4,601 mm; D_i = 4,721 mm; D_i = 4,801 mm; D_i = 4,881 mm; D_i = 5,001 mm; D_i = 5,121 mm; D_i = 5,201 mm.

The rollers working radius values studied is: R = 50 mm; R = 75 mm; R = 100 mm.

The friction coefficient values involved in the analyzed process are: μ = 0.05; μ = 0.10; μ = 0.20; μ = 0.30; these values are comparable with the value of friction coefficient used in conventional rolling.

The chosen values in the study can be compared with those of conventional rolling and drawing processes.

For the rolling force (P) calculation was used the relation:

$$P = p_m \cdot S_c \quad [\mathrm{N}] \tag{1}$$

Where p_m is the average pressure of rolling [N/mm^2]; S_c - contact surface roll/sample [mm^2].

Average pressure of rolling was calculated with the following relation:

$$p_m = \frac{2k}{\Delta h} \cdot \frac{h_n}{\delta} \cdot \left[\left(\frac{h_0}{h_n} \right)^{\delta} + \left(\frac{h_n}{h_1} \right)^{\delta} - 2 \right] \quad [\mathrm{N/mm^2}] \tag{2}$$

Where 2k is rolling resistance, 2k=80 [N/mm^2]; Δh - absolute reduction; h_0 - sample height before deformation [mm]; h_1 - sample height after deformation [mm];

$$\Delta h = h_0 - h_1 \tag{3}$$

Where h_n is height neutral plane [mm];

$$h_n = h_1 \cdot \left[\frac{1+\sqrt{1+\left(\delta^2-1\right)\cdot\left(\frac{h_0}{h_1}\right)^{\delta}}}{\delta+1} \right]^{\frac{1}{\delta}} \quad [\text{mm}] \tag{4}$$

$$\delta = 2\cdot\mu\cdot\frac{l_c}{\Delta h} \tag{5}$$

Where μ is friction coefficient, μ = 0.05; μ = 0.10; μ = 0.20; μ = 0.30; lc - contact arc length [mm];

$$l_c = \sqrt{R\cdot\Delta h} \quad [\text{mm}] \tag{6}$$

Where R is roller working radius, R = 50 mm; R = 75 mm; R = 100 mm. Contact surface roll/sample was calculated with the following relation:

$$S_c = l_c \cdot b_m \quad [\text{mm}^2] \tag{7}$$

Where l_c - contact arc length [mm]; b_m - average width of the sample [mm].

$$b_m = \frac{d_0 + b_{oval}}{2} \quad [mm] \tag{8}$$

For the drawing force [N] calculation was used the relation:

$$F_F = n_\sigma \cdot \sigma_s \cdot \frac{\pi}{4}\cdot b\cdot h_1 \quad [N] \tag{9}$$

Where n_σ is drawing force coefficient of tension stress;

$$n_\sigma = \left[1-\left(\frac{h_1}{h_0}\right)^{\frac{4}{\pi}}\right] \tag{10}$$

Where h_0 is sample height before deformation [mm]; σ_s - flow stress, $k_{fm} = \sigma_s = 80$ [N/mm^2].

3. Results and Discussions

The rolling force is the first force involved in the wire drawing in cassette roller die. This is influenced by a number of parameters, such as: the average pressure of rolling, the contact surface, the working rollers radius, the resistance to deformation, the friction coefficient and the elongation coefficient.

The rolling force increases in direct proportion with the elongation coefficient (Fig. 2), for values higher than 1.15, the more the higher the radius rolls, the results can be compared with specialized literature [11].

Fig. 3 shows that the rolling force has a linear increase with both: radius of work rolls and friction coefficient.

Both this cases are explained by the increased contact surface and friction component of the rolling force.

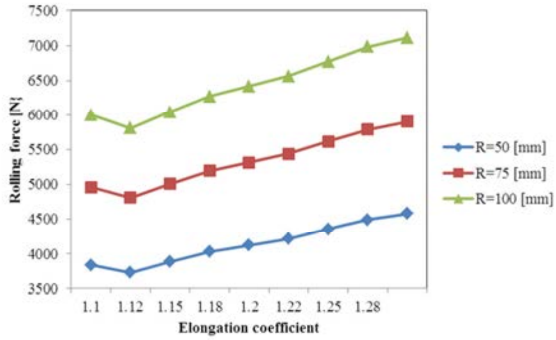

Fig. 2. The variation of rolling force depending on the elongation coefficient, for μ=0.20

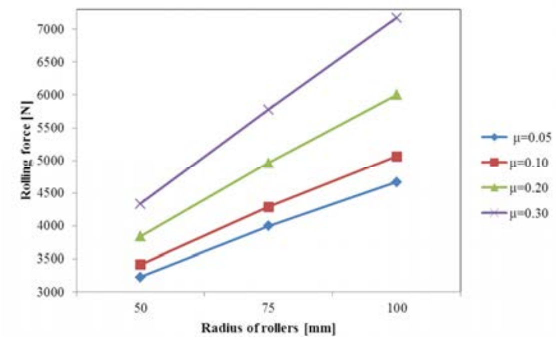

Fig. 3. The variation of the rolling force based on the working roller radius, for λ=1.10

As we can observe in Fig. 4, with the increase in the friction coefficient, increases the average pressure of rolling. The analyzed values of the initial diameters of the samples are very close, but we can observe that increasing the initial diameter of the samples, decreases the average pressure of rolling.

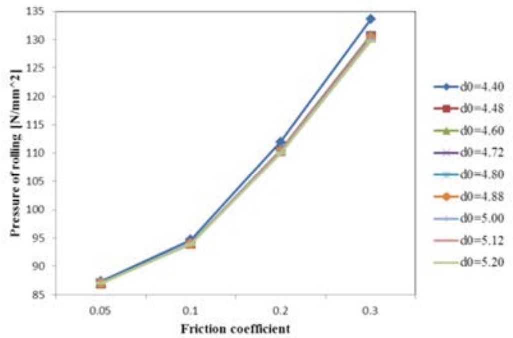

Fig. 4. The variation of average pressure of rolling according to the friction coefficient, for the roll radius 100 mm

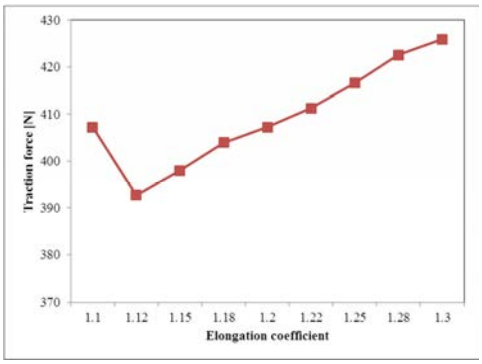

Fig. 5. The variation of drawing force depending on elongation coefficient

The second force involved in the wire drawing with cassette roller dies is the drawing force. This is influenced by the elongation coefficient (Fig. 5). The drawing force increases in ratio with the increase of the elongation coefficient, except an elongation coefficient of 1.10.

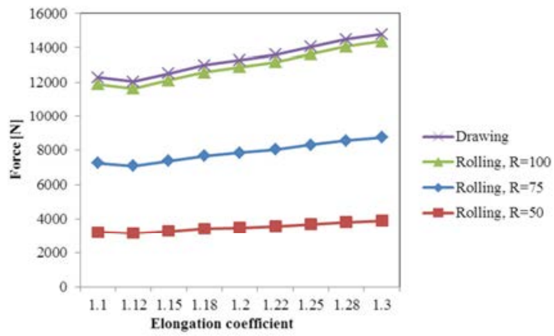

Fig. 6. The variation of drawing forces depending on elongation coefficient

On Fig. 6 we can observe the variation of rolling and drawing forces depending on the elongation coefficient. The drawing force is smaller than the rolling force, because the sliding friction between wire and roller is converted to rolling friction, for example, at roll radius R = 50 and elongation coefficient $\lambda = 1.15$, the rolling force is approach 3400 N, and the drawing force is about eight times lower (approach 400 N).

4. Conclusions

Analyzing the rolling force and the drawing force, a device, operating with minimal demands of testing, involves the use of relatively small elongation coefficients ($\lambda \approx 1.12$), but this would mean a lower productivity.

The friction coefficient increases the friction force and an additional load of the device, especially if the working roller radius increases. This is due to growing contact surface wire / roll.

Increasing the working roller radius will have a negative influence on the energy parameters but this will induce the uniformity of deformations on passes. Moreover, growing the working roller radius increases the overall dimensions of the device, making it difficult to process.

Drawing force is smaller than the rolling force, due to the conversion of sliding friction between wire and roller in the rolling friction.

No special environmental issues arise because both are eliminated: the lubrication (sliding friction is replaced by rolling friction) and the previous cleaning steps of the wire, because the process is immune to the wire surface oxides.

The different conditions presented between the friction and the plastic deformation thru drawing in cassette roller die, in comparison to the classic method, we can be easily observed the increase of reductions in cross-sections of the wire, on a pass, and the increasing uniformity of the wire properties, with the impairment on the texture of the finished product.

To validate the theoretical analysis, there still we perform a study with 3D finite element simulations. We will perform studies on the influence of process parameters and tool geometry, the mechanical, structural and morphological characteristics of the obtained wires.

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