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Qualimetric evaluation of aluminum wire deformed by a combined scheme of deformation "pressing-drawing"

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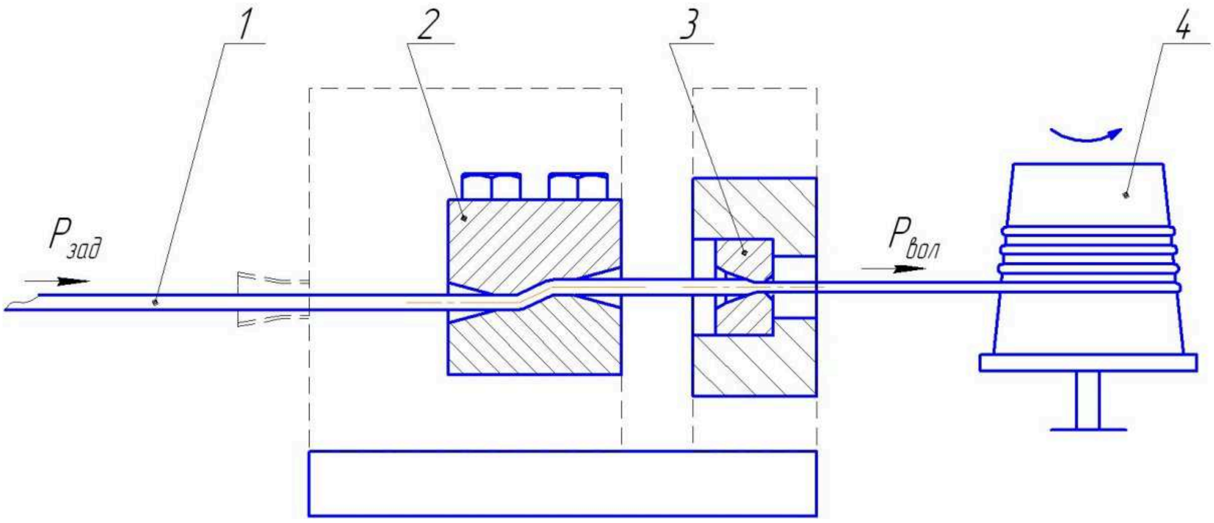
Abstract. In this paper was considered a qualimetric evaluation of aluminum wire deformed by a combined scheme of deformation "pressing-drawing". Comparative analysis of complex quality indicators of deformed aluminium wire in different technologies has proved the advantage of the new technology for the production of wire compared with the existing technology.

Introduction

One of the most promising directions in the field of production of high-quality metals and alloys is the formation of these metals and alloys ultrafine-grained (UMG) structures by methods of severe plastic deformation. However, despite the numerous developments, the most modern methods of implementation of intensive plastic deformation amount of the deformable metal have a number of significant limitations in the aspect of continuity and performance of technological schemes.

One of the promising ways of handling pressure, allowing to remove these restrictions, is the combined process of "pressing - drawing" using equal-channel step matrix and calibrating tool (Fig. 1).



1 - wire; 2 - equal-channel step matrix; 3 - drawing tool; 4 - winding drum
Fig. 1 - Scheme of combined process "pressing-drawing"

The essence of the proposed method of deformation is as follows. Pre-tipped wire is set in the equal-channel step matrix, and then in calibrating drawing tool. Essentially the process of pushing of metal does not differ from the standard process of drawing. After that the end of the workpiece will be exit from the portage it is fixed with the aid of exciting mites and wound on the drum of drawing mill. In this case, the process of pulling the workpiece through equal-channel speed matrix and calibrating drawing tool implemented through application by the end of the workpiece pulling force.

In works [1-5] have already reviewed the impact of the new method of deformation on mechanical properties and structure of steel and aluminum wire.

The purpose of this work, which was carried out in the framework of the state budget theme "Research and development of a combined process of deformation “pressing - drawing" with the aim of obtaining aluminum and copper wire with high mechanical properties and ultrafine-grained structure" for the program "Grant financing of scientific research for 2012-2014", is evaluation of quality of aluminum wire, deformed according to the proposed scheme of deformation “pressing - drawing".

Research methods

To determine the impact of the new continuous method of deformation “pressing-drawing” on the mechanical properties of aluminum wire of grade A0 was conducted a laboratory experiment in industrial drawing mill B- I/550 M. For the implementation of the first cycle of deformation before drawing tool with a working diameter of 6.5 mm was installed equal-channel step matrix from the channel diameter of 7 mm and the angle of junction of the channel in matrix is 135º (Fig. 2). The matrix was placed in a container for lubricant. The shavings of soap were used as lubricant.

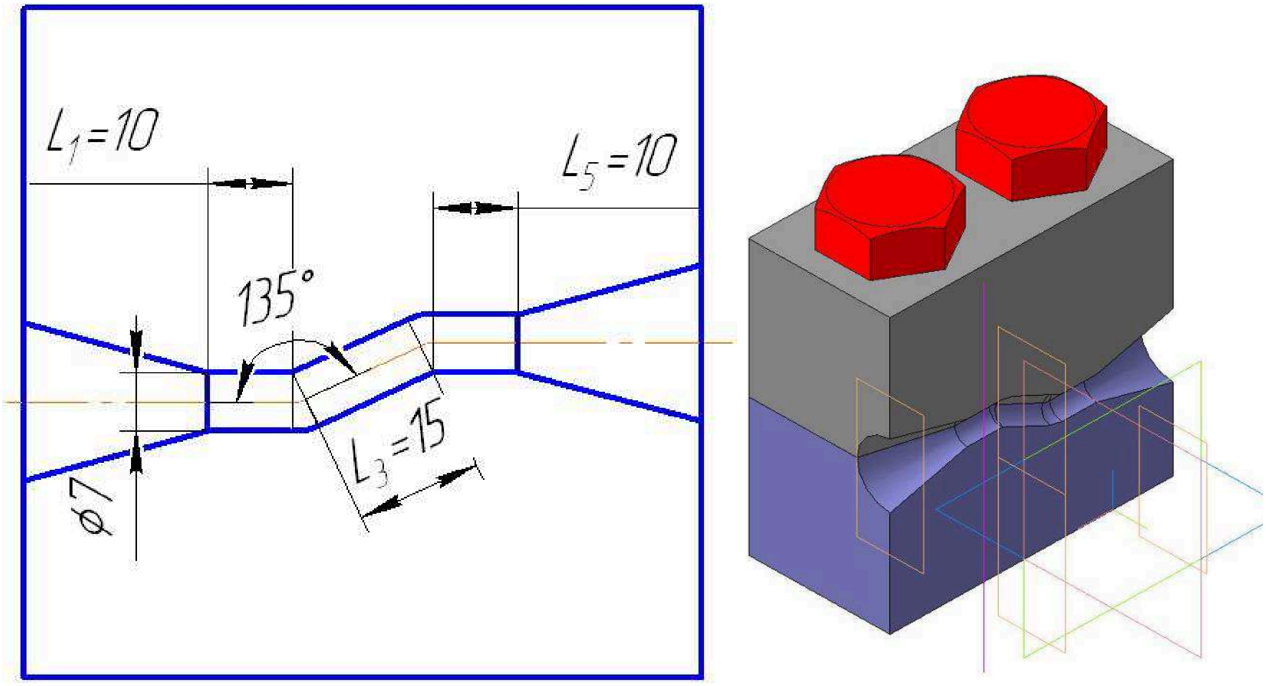


Fig. 2 - Equal-channel step matrix

After pressing-drawing the wire diameter was 6.5 mm. All compression was carried out only in drawing tool, after the output of workpiece from equal-channel step matrix wire diameter remained unchanged and was 7.0 mm Experiment was duplicated three times.

After the first cycle of deformation for further research changed as drawing tool as equal-channel step matrix. So when the implementation of the second cycle of deformation of the working diameter in the drawing tool was 6.0 mm, and the diameter of the channels in matrix was 6.5 mm; in the implementation of the third cycle - 5.5 mm and 6.0 mm respectively.

To identify the advantages of the proposed technology compared to the existing wire production technology was conducted simple drawing of aluminum wire in the drawing tools with diameters 6.5; 6,0; 5,5 mm. Experiment was duplicated three times.

In conventional drawing also was used a shaving soap as a lubricant.

Results and discussion

From deformed wire were prepared samples for tension and bending tests and determination of Vickers hardness.

Tension test of wire in according to GOST 10446-80 were conducted in a Central laboratory JSC "ArcelorMittal Temirtau" on the test machine INSTRON 4486 intended for testing tension /compression to identify the main mechanical characteristics of the wire.

Bending test was carried out according to GOST 1579-93 and serves to measure the ability of a wire to be subjected to plastic deformation during bending.

The test results of samples of aluminum wire, deformed on the proposed and existing technologies, are presented in table 1.

Table 1 – Parameters of mechanical testing of aluminum wire

Technology	Cycles of deformation	Parameters					
		Tensile strenth, [MPa]	Yield strenth, [MPa]	Elongation, [%]	Contraction, [%]	Hardness [HV]	Number of bends
Drawing	1	369	210,3	10,47	28,6	35	12
	2	453,7	310,3	4,6	10,53	40	10
	3	501	350,7	1,63	6,6	47,3	9
Pressing-drawing	1	424,7	283,7	13,57	29,5	38,3	13
	2	487,3	330	6,4	15,73	46	12
	3	537,7	405,7	4,87	10,63	54,3	11

Table 1 shows that with increasing number of cycles the strength characteristics of aluminum wire, deformed on the proposed technology (combined process "pressing-drawing") grow more intensively than strength properties of aluminum wire deformed on current technology. When the deformation of aluminum wire on the proposed technology are reduced less intense than when using current technology. All this allows us to say that the use of the proposed technologies of combined process "pressing-drawing allows you to get high quality aluminum wire with high strength properties, when sufficient plastic properties. Table 1 shows that using the proposed combined technology "pressing-drawing" the number of bends and values of hardness have higher values compared to the use of traditional drawing.

However, the mechanical properties do not provide a comprehensive assessment of the quality of the product, as they are characterized by different properties of the material and have different dimensionality. In this regard, for a full and comprehensive assessment of the quality of the wire used methods of qualimetry given in work [6].

Since in our case all the properties that are used as indicators of individual quality, are at the same hierarchical level (level of mechanical properties), so we can take all the properties of the equilibrium. Then the composite measure of quality K_0 calculated according to the formula:

$$K_0 = \sum_1^n K_i / n, \quad (1)$$

where $\sum K_i$ - sum of all individual quality criteria K_i;

n –number of unit quality criteria K_i.

Single differential quality criterion K_i is defined by the formula:

$$K_i = \exp(-\exp(-y_i^*)), \quad (2)$$

where y_i^* –parameter calculated by the following relations:

$$\left.\begin{array}{ll} \Gamma_i \in [A_1; A_2) & Y^* = 0{,}48165\dfrac{\Gamma_i - A_1}{A_2 - A_1} + 0{,}47588; \\ \Gamma_i \in [A_2; A_3) & Y^* = 0{,}76634\dfrac{\Gamma_i - A_2}{A_3 - A_2} + 0{,}0577; \\ \Gamma_i \in [A_3; A_4] & Y^* = 0{,}72783\dfrac{\Gamma_i - A_3}{A_4 - A_3} + 0{,}77211; \\ \Gamma_i \in (A_4; A_5] & Y^* = 0{,}75043\dfrac{\Gamma_i - A_4}{A_5 - A_4} + 1{,}49994; \\ \Gamma_i \in (A_5; A_6] & Y^* = 2{,}348971\dfrac{\Gamma_i - A_5}{A_6 - A_5} + 2{,}25037. \end{array}\right\} \quad (3)$$

Constants $A_1 \div A_6$ are determined by empirical correlations:

$$\left.\begin{array}{lll} A_1 = \overline{\Gamma} + \alpha_1 \dfrac{S}{\sigma_N}; \; A_2 = \overline{\Gamma} + \alpha_2 \dfrac{S}{\sigma_N}; & & A_3 = \overline{\Gamma} - 2S; \\ A_4 = \overline{\Gamma} + 2S; & A_5 = \overline{\Gamma} - \alpha_2 \dfrac{S}{\sigma_N}; & A_6 = \overline{\Gamma} - \alpha_1 \dfrac{S}{\sigma_N}, \end{array}\right\} \quad (4)$$

where $\overline{\Gamma}$ - average natural rate of mechanical properties Γ_i, obtained for the set of N experimental values;

S – standard deviation;

α_1, α_2 - coefficients determined from the ratios (5);

σ_N - parameter determined from the ratio (6).

$$\alpha_1 = Y_N - 7{,}565\frac{\sigma_N}{\sqrt{N}} - 2{,}97; \qquad \alpha_2 = Y_N - 2{,}97, \quad (5)$$

where the parameters Y_N and σ_N can be determined by dependencies:

$$Y_N = a + b \cdot \ln N; \qquad \sigma_N = c + d \cdot \ln N, \quad (6)$$

where a, b, c, d - empirical coefficients [6].

The calculation of the integrated quality indicator by the above method was made using the program "Calculation of complex indicators of quality" [6]. The calculation results are shown in table 2.

Table 2 - Differential and integrated quality indicators

Technology	Cycles of deformation	Differential indicators						K_0
		K_{TS}	K_{YS}	K_δ	K_ψ	K_{HV}	K_{bend}	
Drawing	1	0,669	0,684	0,676	0,679	0,664	0,701	0,677
	2	0,717	0,726	0,716	0,707	0,699	0,695	0,713
	3	0,735	0,748	0,733	0,723	0,732	0,695	0,734
Pressing-drawing	1	0,745	0,761	0,736	0,729	0,761	0,701	0,746
	2	0,785	0,773	0,790	0,788	0,785	0,701	0,784
	3	0,788	0,783	0,806	0,900	0,794	0,701	0,814

For a clearer presentation of the evaluation results of the mechanical tests using a comprehensive quality assessment method of drawing and the number of passes we will construct the graph of a comprehensive assessment of quality aluminum wire from the way of drawing and the number of passes (Fig. 3).

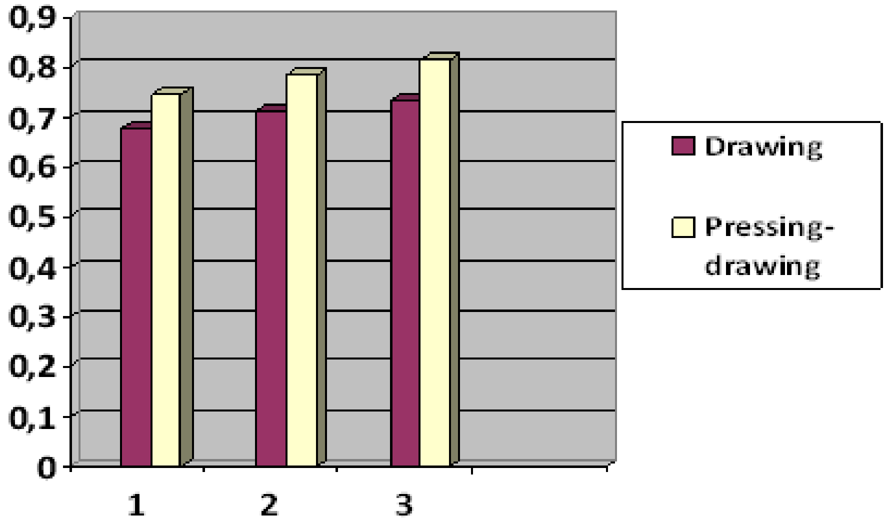


Fig. 3 - The graph of a comprehensive assessment of quality aluminum wire from the way of drawing and the number of passes

Conclusions

Comparative analysis of complex quality indicators of deformed aluminium wire in different technologies has once again proved the advantage of the new technology developed for the production of wire of non-ferrous metals and alloys - combined process of deformation “pressing-drawing” compared with the current technology of wire drawing, that is, the proposed wire production technology of non-ferrous metals and alloys provides the best quality of metal compared with the existing technology.

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