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Improving Energy Efficiency of Drawing Equipment through Energy and Resources Saving

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ABSTRACT: The article deals with the issue of improving effectiveness of operation of straight-through drawing machines. Analysis of applied technology of drawing allowed formulating of technical solution for improvement of the conductor qualitative indicators of cabling and wiring production by reducing fragmentation of metal deformation in its drawing. This is achieved by drawing route recalculation and thereby it allows improvement of energy efficiency of the straight-through drawing equipment operation. The experimental part included reduction in the number of drafts of existing drawing route, which in turn led to reduction in the number of drives, applied in the process of drawing, and to 20% reduction of power consumption of the straight-through drawing machine. Improvement of qualitative parameters of the conductor included reducing the electrical resistance of the drawn sample for copper to 3% and for aluminium-1.5% and enhancing its transmission capacity.

I. INTRODUCTION

In the conditions of growing requirements to reduce losses during electric energy transmission through cable lines, not mechanical, but electric-physical properties of cable products occur to be critical. That is why creation of wires of electrical –technical copper and aluminum with not only high strength characteristics, but high conductivity is of great importance for industry. Research, conducted in the field of study of current –conducting conductor (CCC) quality improvement, reduces to definition of parameters of electricity transmission and the factors, influencing it. Transmission parameters are characterized by uniformity and propagation of electromagnetic energy over the entire length of the conductor without obstacles, so solution of reducing CCC electrical resistance will increase performance characteristics of the whole cable product. In this regard, we consider technological process of drawing as a basic stage of providing qualitative parameters of cabling and wiring products.

Technological process of wire drawing can be performed in different ways, while spinneret method is the basic one for all kinds of drawing machines, because it provides higher quality of drawn wire [1]. Therefore, technological operation of drawing for all types of cabling and wiring products (CWP) is the beginning of manufacturing technology, while improving efficiency of production and ensuring high quality of products are the main task, being solved by cable manufacturers.

II. PREREQUISITES OR RELATED WORKS

Theoretical research in this field [2, 3, 4], analysis of cable companies experience and their drawing technologies led to the conclusion that the task of increasing efficiency of existing production could be solved both by technical re-equipment of enterprises, with the introduction in production of new progressive technological equipment, and by modernization of installed technological equipment in order to improve performance of drawing machines (DM) and

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to reduce percentage of industrial waste, with obligatory observance of the conditions of the high quality preservation of drawn wire.
The question of enhancing effectiveness of the drawing process is being addressed now: by application of processing lines; use of multiwire drawing; reduction of power consumption of technological equipment; selection of optimal parameters of emulsion; extension of service life of technological tool-dies; using high-quality blanks (wire rod); improvement of technologies and equipment modernization with the introduction of resource-and energy-saving electromechanical systems (EMS) [4, 8].

When drawing the wire, in metal structure, plastic deformations occur which lead to a proportional change (reduction) of the object cross-section and increase of its length, as well as change of metal microstructure. This fact is negative, because it worsens properties of drawn metal (changing electrical and mechanical parameters) [39, 19-22].

When considering enhancing the drawing process, one cannot look out for only factors, relating to improving operation of the technological equipment, improvement of CCC quality shall be taken in consideration too, i.e., of cable and wire products in general. Studies in this area have concluded that operational properties of drawn wire depend on technology, because it forms microstructure of drawn metal. Therefore, the question of DM effectiveness should be considered in conjunction with the quality improvement of drawn wire that has not been carried out previously.

Research of BerinI.Sh. and N.Z. Dniestrovskiy [5], conducted in the field of CCC quality enhancing, indicates increase of wire electrical resistance in cold plastic deformation of copper to 3% and aluminum -to1.5% due to fragmentation of drawn metal deformation (fig. 1). It follows from this that reducing CCC electrical resistance depends on fragmentation value of microstructure deformation of drawn wire, which intensifies along drafts. Therefore, solving the question on revision of the drawing route towards decreasing its multiplicity, while maintaining the blank input diameter and output wire diameter, can give good results regarding increase of CCC transmission capacity.

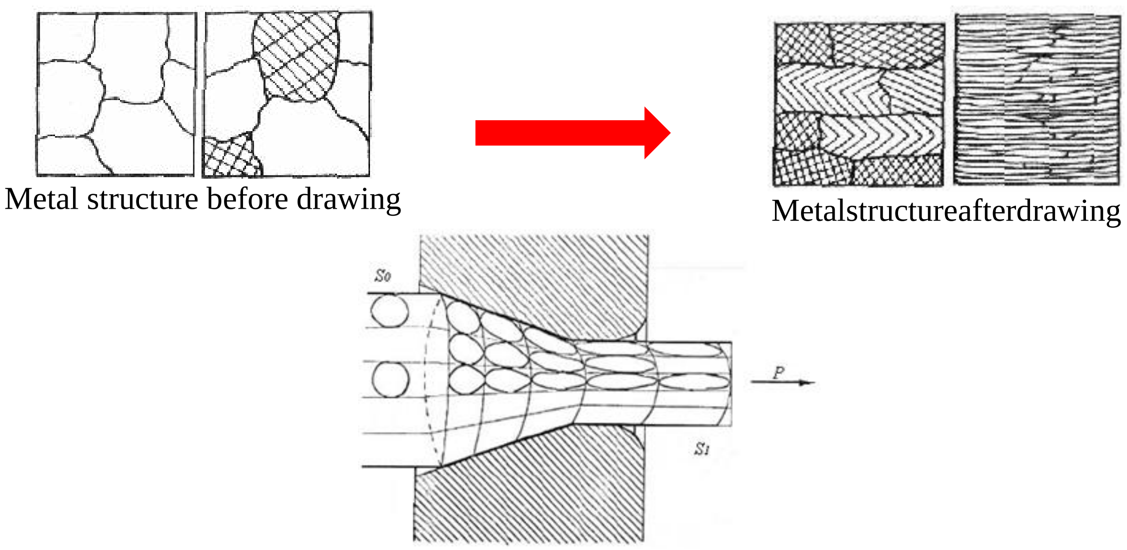

Fig.1 Process of change of solid profile of the processed object in the course of the drawing process.

Structural analysis of micro-section of drawn copper wire samples confirmed that according to the drawing route, the blank microstructure:
- of copper wire rod (diameter 8.0 mm) is compacted, influencing ohmic resistance of the drawn sample, reducing CCC electrical conductivity (fig. 2) by 3%.

Drafts along the drawing route

Sample of copper rod, 8mm

Sample of copper 8,0 mm	№1	№2	№3	№4	№5	№6	№7	№8	№9	№10	№11	№12	№13

Fig. 2 Microstructure of drawn sample of copper CCC

- of aluminum rod (diameter 9.5 mm) is compacted slightly, compared to the copper sample, but also decrease of electrical conductivity by 1.3% is recorded (fig.3).

Drafts along the drawing route

Sample of alum. rod 9,5 mm	№1	№2	№3	№4	№5	№6	№7	№8	№9	№10	№11	№12	№13

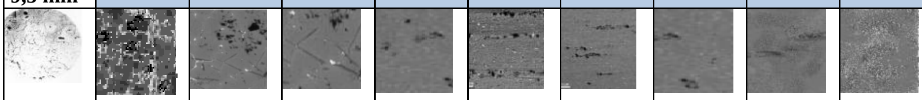

Fig. 3 Microstructure of drawn sample of aluminum CCC

III. PROPOSED METHODOLOGY AND DISCUSSION

Thus, the question of reducing CCC electrical resistance can be solved by reducing deformation fragmentation by reducing the number of drafts along the drawing routes, i.e. reducing working areas of plastic deformation (technological tool-drawing die) where structural changes occur.

Straight-through DM, having drawing blocks with individual electric drives, was adopted as the object of study.

Chosen design of the technological equipment would allow disabling of electromechanical systems (EMS) of DM without breaking technological cycle and with properly calculated drawing route would allow redistributing evenly of drawing effort among operation areas along drafts. Drawing force of the whole process, acting in straight-through DM is determined by the parameters of the main drive (ED) and is calculated on drawing routes, maintaining tension in DM system.

Study of electromechanical system of straight-through drawing machine was based on the developed by Linkov S.A. [2] mathematical model (fig. 4). Based on previously defined parameters of the drawing process and using a system of differential equations in operating view model of multiple straight-through drawing machine has been studied with respect to the proposed operating conditions (1).

Conducted research work allowed considering different versions of operating modes of the straight-through drawing machine and determining the optimal multiplicity of drawing process with provision of technology effectiveness in general.

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$$\left.\begin{aligned}
&M_{дин_n}(p) = M_{дв\ n}(p) - P_n(p)\frac{R^{вх}_{б\ n}}{j_{ред\ n}} + Q_{(n-1)}(p)\frac{R^{вых}_{б\ n}}{j_{ред\ n}} - M_{хх\ n}(p);\\
&\omega_{дв_n}(p) = M_{дин\ n}(p)\frac{1}{J_{\Sigma n}\,p};\\
&v^{вх}_{б_n}(p) = \omega_{дв\ n}(p)\frac{R^{вх}_{б\ n}}{j_{ред\ n}};\\
&v^{вых}_{б_n}(p) = \omega_{дв\ n}(p)\frac{R^{вых}_{б\ n}}{j_{ред\ n}};\\
&P_i(p) = (v^{вх}_{б\ n} - v^{вых}_{в_n})\frac{EF_n}{L_{p\ n}p}\\
&v^{вых}_{в_n} = v^{вых}_{в_n}\mu\\
&v^{вх}_{в_n} = Q_i(p)\frac{L_{Q_n}p}{EF_{(n-1)}} + v^{вых}_{б(n-1)}\\
&Q_n(p) = P_n(p) - N_n(p)
\end{aligned}\right\} \quad (1)$$

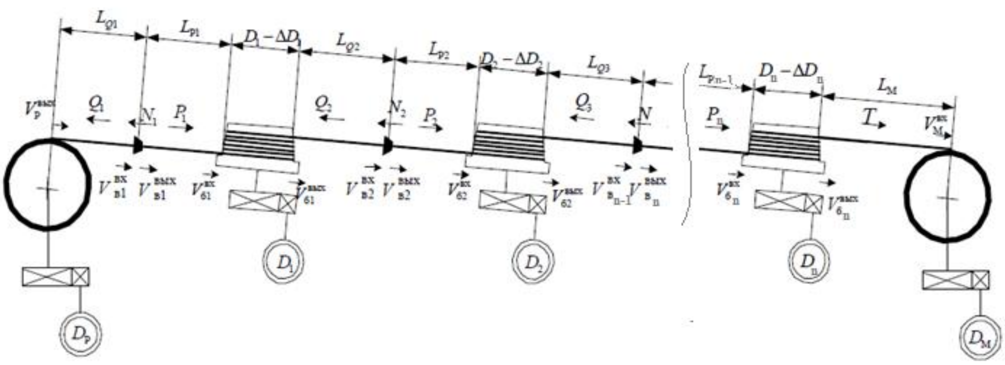

Fig.4 Design scheme of n- multiple straight-through drawing machinecopper wire drawing [2]

Simulation of drawing process of copper and aluminum wire was held for several types of straight-through drawing machines: VPTs4-550 and NIEHOFF using generalized block diagram (fig. 5), made on the basis of equations system (1).

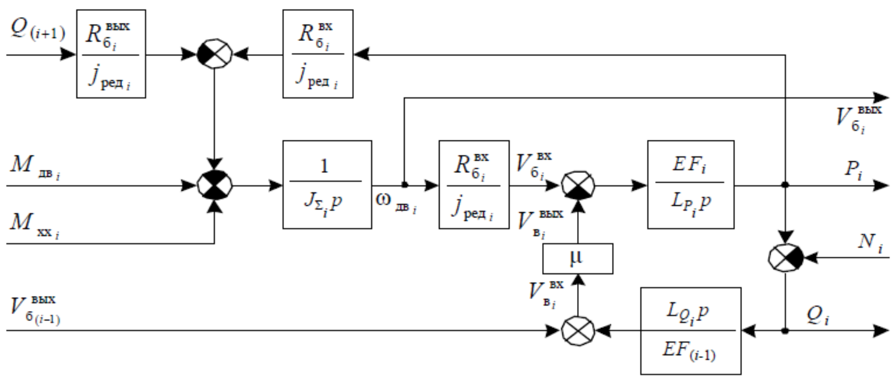

Fig.5 Block diagram of mathematical model of inter-drum spacing [2].

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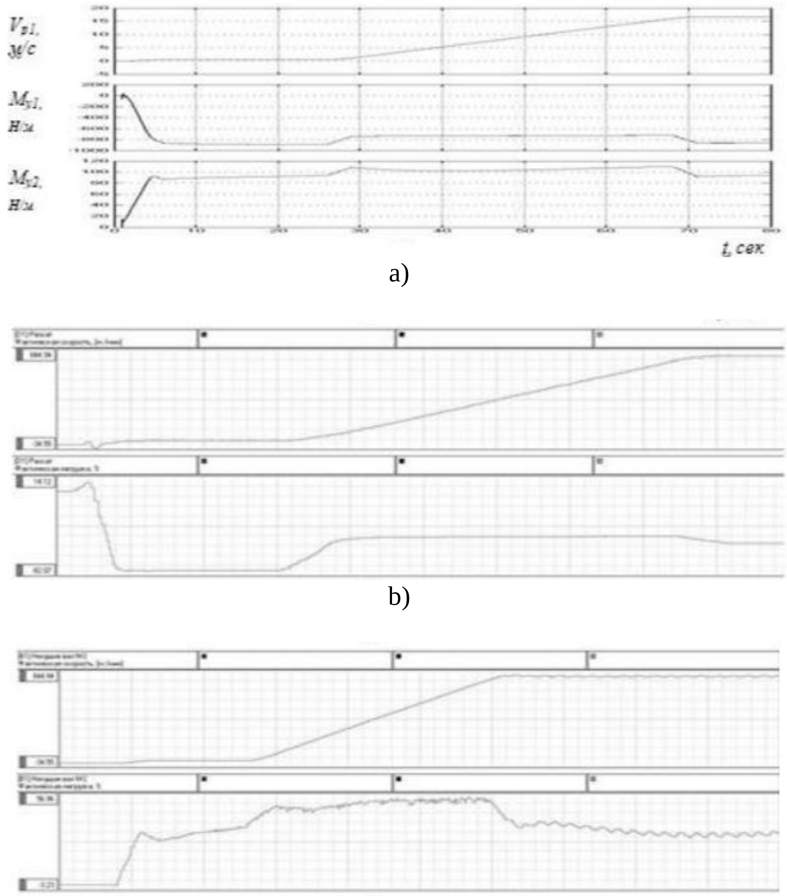
The results of simulation of drawing process confirmed correctness of recalculation of the drawing route for complete work cycle of the straight-through drawing machine (fig.6).

IV. EXPERIMENTAL RESULTS

The experimental part of the study was conducted on two multiple straight -through DMs: VPTs 4-550 and NIEHOFF, installed at «NAVOI CABLE CONNECTOR» LLC (Navoi city). As a result of the carried out research work and industrial experiments (fig.8, a,b) it was found that reduction in drafts from 13 to 10 (NIEHOFF), and for VPTs 4-550 from 10 to 6 д gave the result of quality improvement of copper wire samples in average to 15% (fig. 6). Re-calculation of drawing route to the smaller number of drafts allowed excluding from the technology two idle drawing blocks that did not impact on the quality of CCC production and DM work.



a)

b)

c)

fig. 6. Fragments of results of simulation (a)and industrial experiments (b, c)

Obtained estimates and the results of industrial experiment confirmed correctness of the decision to switch off PS of DM drawing blocks (table 1). Also industrial experiment was conducted for drawing machines with the main electric drive (type VSK-13), however, positive results were obtained only regarding improvement of the quality of drawn copper wire samples (reducing of ohmic resistance), in respect of improving the energy efficiency of the process for this specific case-options remained unchanged, since DM had one main drive that cinematically was connected with the intermediate block and hence rerouting to the specified output diameter reduced to changing the number of engaged washers.

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Comparative analysis of drawing process parameters

Drawing process parameters	**Common PS for DM**		**Individual PS for each IB**	
	Operating	Rated	Operating	Rated
1	**2**	**3**	**4**	**5**
Number of drafts, PCs.	10	6	7	5
Number of electric drives	1		7	5
Power consumption, kW	252		45	33,2
Material	Copper			
Drawn Product	Round wire		Shaped wire	

V. CONCLUSION

Reducing the number of idle EMS has resulted in lower power consumption of DM by 27%, which refers this solution to energy saving. Also bearing in mind that in the production of wires and electric cables-drawing is the basic operation for giving to future wires, conducting cores and cables of their main properties and assignment - effective and low-cost transportation of electric energy, this fact can also be seen as energy efficiency, but for power transmission systems.

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