Management Aspects Related to the Optimization of the Technological Operation of Cutting by Electric Erosion with Contact Breaking

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Abstract: *This scientific paper presents some aspects related to the management of the optimization of processing operations by electrical erosion with contact breaking. The introductory part contains a series of theoretical considerations on the approached field, highlighting the importance and role of optimizing such a process. The criteria for achieving an optimization process in this way, in the industry, as well as the restrictions imposed by them in optimizing the cutting are also analyzed. In the last part of the research are presented the own points of view and the conclusions derived from this study that point out the need to correlate the technological, mechanical and working parameters in the electrical erosion process. At the same time, the way in which this process can be improved in the sense of creating favorable conditions regarding its stability was highlighted.*

Keywords: *electrical erosion, operation, optimization, processing object, transfer object*

1 THEORETICAL CONSIDERATIONS

Optimization can be defined as an activity of detecting, applying and maintaining the best solution in a given set, based on an optimization criterion by the objective function, a solution that respects the restrictions imposed on the independent variables considered in the description of the objective function (Ahmad Mufti et al., 2020).

The optimization starts from the premise of the existence of an objective function, which quantitatively describes the variation of the studied phenomenon or process (Chaudhari et al., 2020), (Markopoulos et al., 2020), (Rafaqat et al., 2020), (Ezeddini et al., 2020).

The main categories of optimization criteria are presented in Figure 1.

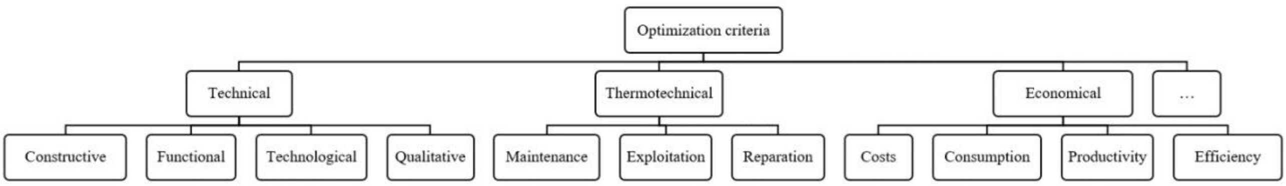

Fig. 1. Optimization criteria used in industry

2 USE OF CRITERIA IN CARRYING OUT THE PROCESS FOR OPTIMIZING CUTTING TECHNOLOGY IN INDUSTRY

The industrial sectors (metallurgy, machine building, etc.) are constantly facing great difficulties related to the production and optimal sizing (at predetermined lengths) of different types of laminates in the class of steels and high steels alloy, as well as for the execution of operations to remove weights or power grids for certain categories of castings (Ablyaz et al., 2020), (Abu Qudeiri et al., 2019).

The current way of organizing the cutting of materials from the range of steels alloy, reflects a low degree of loading of equipment, as well as a significant coefficient of "waste", which could be the "raw material" for other economic activities (Chen et al., 2020), (Koshy et al., 2015).

The existing equipment is highlighted by the presence of a large number of machines with low productivity, as well as large production areas used improperly (Niamat et al., 2020).

The multiple problems determined by the demand-supply relations specific to the market economy, require a diversification of activities and rapid possibilities to adapt to these conditions (Marrocco et al., 2020), (Sabyrov et al., 2019), (Wang et al., 2013).

One of the actions through which the organizations in the metallurgical industry or in the construction of machines can adapt more efficiently to the requirements of the market economy, is the achievement of an increase of productivity and quality of work, by centralizing cutting operations (and forging) in specialized units with specific equipment - electric erosion with contact breaking – (EECB), which can be organized in the form of "single centers" (specialized compartments) for cutting and forging (as appropriate).

Taking into account this proposed specialization, the following technical-economic criteria are considered that can characterize and provide a complete picture for the proposed objective:

A. The technical criterion
   a. constructive (dimensional);
   b. technological;
   c. qualitative;

B. The economic criterion
a. costs;
b. consumption;
c. productivity;
d. economic efficiency.

3 ANALYSIS OF CUTTING PRODUCTION PROCESSES BASED ON SPECIFIC CRITERIA

3.1 Dimensional criterion

It allows the characterization of production processes by breaking down the activity according to the form of semi-finished products and parts to be cut.

Depending on the geometric configuration established in the construction documentation, the semi - finished products and parts can be grouped, according to Table 1.

3.2 Technological criterion

This criterion characterizes the production processes (cutting) and ensures the development of cutting operations for semi-finished products and parts on the technological flow.

3.3 Qualitative criterion

The application of the qualitative criterion ensures that the finished laminates and metallic materials to be introduced in the production process (when cutting) correspond to some quality categories.

Depending on the number of parts or semi-finished products, control technologies will be prescribed, which will take into account the accuracy class provided in the construction documentation.

Table 1. Grouping of workpiece products and parts according to the geometric configuration established in the construction documentation

Group	Nature of the material	Weight G [kg]	A [mm^2] P [mm]	Simbol	Sheet metal thickness s [mm]
A	Medium and light profiles	$G_1 \leq 100$	$A_1 \leq 2500$	A_1	
		$101 \leq G_2 \leq 500$	$2501 \leq A_2 \leq 5000$	A_2	
B	Heavy and workpiece profiles for forging	$G_1 \leq 100$	$A_3 \leq 2500$	A_3	
		$G_1 \leq 100$	$2501 \leq A_4 \leq 5000$	A_4	
		$101 \leq G_2 \leq 500$	$A_5 \leq 2500$	A_5	
		$501 \leq G_3 \leq 1000$	$A_6 \leq 2500$	A_6	
		$501 \leq G_3 \leq 1000$	$2501 \leq A_7 \leq 5000$	A_7	
C	Medium and thick sheet	$G_1 \leq 100$	$P_1 \leq 10000$	P_1	$5 \leq s \leq 12$
		$G_1 \leq 100$	$P_2 \leq 2500$	P_2	$12 \leq s \leq 50$
		$101 \leq G_2 \leq 500$	$P_3 \leq 10000$	P_3	$12 \leq s \leq 50$
		$1001 \leq G_3 \leq 5000$	$P_4 \leq 10000$	P_4	$50 \leq s \leq 100$
		$G_4 > 5000$	$P_5 \leq 5000$	P_5	$s > 100$
		$G_5 > 5000$	$P_6 > 5000$	P_6	$s > 100$
A - material section for cutting (forging) P - perimeter of the material for cutting, straight contour					

3.4 Economic efficiency

It comprises a wide range of elements with which the results obtained can be quantified.

The increase of the economic efficiency presupposes for this case the continuous improvement of the forms and methods of organization and management of the activities specific to the “single center” or “specialized compartments” (cutting and / or forging), as well as the judicious management of the equipment.

The production activity thus organized will lead to:
- reducing the duration of the manufacturing cycle;
- ensuring rhythmicity and continuity by organizing the manufacture (cutting) in batches;
- achieving an optimal degree of loading of the equipment.

The economic effects of organizing the cutting of high-alloy steels (semi-finished products, parts or castings) within a "single center" or "specialized compartments" will be highlighted by the following aspects:

a) the possibility of executing technological operations within specialized industrial lines, with production processes carried out in continuous flow;

b) the possibility of applying computer-aided design for the cutting operations of semi-finished products, parts or castings (weights or supply networks);

c) the optimal loading of the equipment and their location within the industrial lines, based on the optimization of the production processes.

4. USE OF CRITERIA AND RESTRICTIONS IN OPTIMIZING THE TECHNOLOGICAL OPERATION OF CUTTING THROUGH ELECTRIC EROSION WITH CONTACT BREAKING

One of the major problems of the EECB it is the optimization of technological cutting operations. Carrying out a correct study on the aspects related to the optimization of the cutting operation through EECB, requires the determination of some technical-economic criteria that are the basis of this process, as well as the reflection of some restrictions determined by the components of the work process.

4.1 Use of criteria optimization of cutting

From the category of constructive and technological criteria the most important are those that take into account:

a) the transfer object;
b) the processing object;
c) cutting equipment;
d) power supply.

Criteria considering transfer object

This category includes aspects related to the constructive and technological improvement of the execution of the transfer object.

The constructive and technological solutions adopted (the shape of the joint of the ends of the metal strip, the technology of welding or processing of the ends, etc.) aimed at:

- reduction of costs with the execution of transfer object;
- reduction of wear determined by the quality of the material from which the transfer object;
- increasing the working time of transfer object and implicitly the increase of the cutting productivity.

Criteria considering the processing object

The specific elements aim in this case to achieve an optimization of the cutting process, taking into account the object of processing, its main characteristics.

The following are considered:

- the quality of the material to be cut;
- processing object;
- cutting time;
- the quality of the surface resulting from the cutting of processing object.

Criteria for the cutting machine

The equipment designed and executed for cutting through EECB, meets the optimization criteria. When designing the machine, the aim was to ensure some parameters (electrical, mechanical, etc.) in full accordance with the sections to be cut (Φ_{max} = 50mm, S_{max} = 2000mm^2).

The constructive elements of the designed machine ensure the overall reduction of the costs generated by the cutting operation.

Criteria that take into account the power supply

The power supply and the generation of the erosive agent are made from a power supply type RC-1000A, ELECTROTEHNICA, Bucharest. This source ensures the necessary electrical parameters (I, U, J, etc.) to carry out in good conditions the cutting operations for the designed sections.

Appropriate cutting regimes (hard, soft) can be made for the different sections to be cut.

The category of the qualitative criterion includes those that consider: a) the quality of the cut; b) cutting accuracy; c) thermal influence zone.

Thus, the quality of the cut is determined by the level of surface roughness (R_a) obtained after cutting. The measurements performed showed values for Ra between 10 and 20µm.

The cutting of surfaces also requires a certain precision of cutting, which is largely influenced by:

- the level of wear of the transfer object - processing object;
- constancy of transfer object pretensioning;
- correlation of the advance speed of the metal band with the pressing force on the part, avoiding the modification of the perpendicularity of the strip on transfer object.

At the same time, on the cutted surface of processing object a thermal influence zone will be formed, characterized by microstructural changes and microcracks, which will influence the depth and microstructure of the thermally influenced layer.

The category of economic criteria includes the whole range of components that participate in the economic reflection of the debit operation.

The general calculation relation for this case is:

$$C_T = C_{OT} + C_D + C_{IDN} \text{ [RON/cut]} \quad (1)$$

Where: - C_T is the cutting cost;
- C_{OT} is the cost of obtaining the transfer object.

$$C_{OT} = C_F + C_M + C_{SDV} \text{ [RON/piece]} \quad (2)$$

Where:
- C_F is the manufacturing cost of the transfer object;
- C_M is the cost of materials the composing the transfer object;
- C_{SDV} is the cost of special tools checking devices for the execution of the transfer object;
- C_D is direct costs;
- C_{IDN} is indirect costs.

Lower C_T values are obtained by use in the transfer object manufacture materials that have a minimum cost price (OL 37, OL 32, etc.), with an execution technology that incorporates low costs and requires a small number of special SDVs.

4.2 Use restrictions to optimize the cutting

Depending on the items to which they relate, restrictions can be grouped by:

- the processing object;
- the transfer object;
- cutting machine;
- power source.

Restrictions imposed by the object of processing

The quality of the materials to be debited is one of the important restrictions to consider. The EECB can be applied to a wide range of product qualities, but its efficiency is most pronounced in the case of qualities of materials difficult to cut by other processes, mentioned below:

- steels or high steels alloy, heat treated before cutting (C120 improved to 60HRC, 34MOCN15, 41MOC11, RUL-1, etc.);
- hard alloys of different brands and types of dimensions for which the cutting processes are inefficient;
- heat - treated or thermochemically treated steels, to which, for economic or technological reasons, no other

conventional processing operations are applied before the cutting operation (eg. ionic nitride steels, etc.);

- cast steel parts, high alloys, from which the weight and the supply networks must be removed, in conditions of economic efficiency.

Restrictions imposed by the transfer object

In the EECB process, the transfer object has a direct influence on both the accuracy of the cutting and its costs.

Experimental research has allowed the use of low-alloy carbon steel materials (STAS-1945/90), with a much lower cost price.

Another category of restrictions is related to the metal band (transfer object).

The optimal design variant is currently the joining by welding of the ends of the strip, heads prepared according to a suitable technology.

Restrictions imposed by EECB cutting machine

The dimensions that could be cut on the designed and executed cutting machine, during the experimental research, were between 10 and 50 mm.

This category of restrictions specific to the cutting machine could be satisfied by the constructive solutions adopted during the experimental research.

Restrictions imposed by the power supply

The need to carry out the cutting process according to certain regimes (soft, normal, hard) determined that the source of generation of the erosive agent to ensure certain values of the working voltage (8-22V). At the same time, the maximum sections expected to be cut (max. 2000mm^2), required the source to provide the necessary electrical parameters for these sections (current, voltage, current density).

5 CONCLUSIONS

It is found that, depending on the mechanical and technological parameters provided to be used, the other sizes of the working parameters of the cutting process can be correlated by EECB.

At the same time, by improving the way of gathering information from the work gap (transfer object-processing object), the advance system and ensuring an adaptive control of the cutting process, it will be possible to radically change the way the cutting process is carried out, reducing at the same time the range of existing restrictions and creating more favorable conditions on the stability of the cutting process.

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