CONTRIBUTIONS ABOUT USAGE OF FUZZY SETS FOR OPTIMIZING THE PROCESSING PARAMETERS OF ELER-01-GEP-50-F MACHINE

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ABSTRACT

This paper presents an application of fuzzy sets concerning the optimization of the ELER-01-GEP-50-F machine operating conditions. The starting point consists of the criteria according to which the operating parameters (productivity and roughness) are determined, and the output variables of the decisional process (current intensity, impulse and pause times) are established. The optimized values of the output variables are obtained according to the required values of the operating parameters.

KEYWORDS: fuzzy sets, electrical erosion, roughness, impulse time, pause time

1. INTRODUCTION

The electrical erosion machining with massive electrode, as a method of dimensional machining of metallic materials, may be seen as a technological action system. In a systematic approach, the electrical erosion features the following three known factor categories:

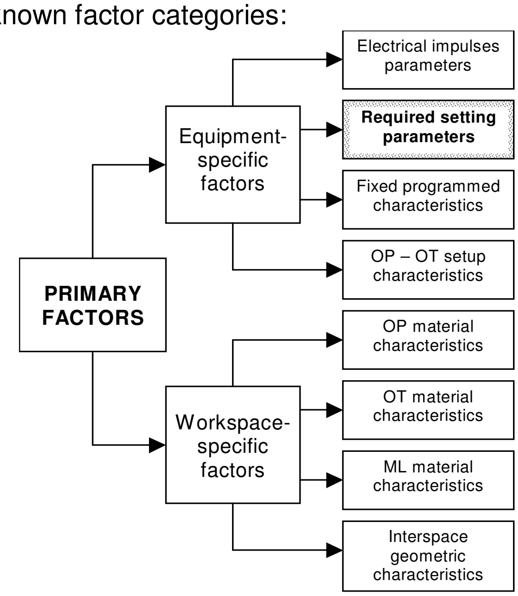

Fig.1. Primary factors of the electrical erosion processing

- *Primary factors (input variables)*, which represent the environment actions on the system;
- *Intermediary factors (process variables)*, represented by the process itself;
- *Final factors (output variables)*, which represent the action response on the environment, as technological, technical and economical characteristics.

Because there are many factors that can influence the electrical erosion processing, there is the possibility of using fuzzy sets techniques for optimizing the machining process parameters. This paper shows a procedure based on fuzzy sets for the determination of the operating conditions parameters (current intensity, impulse and pause times) specific to the ELER-01-GEP-50-F machine.

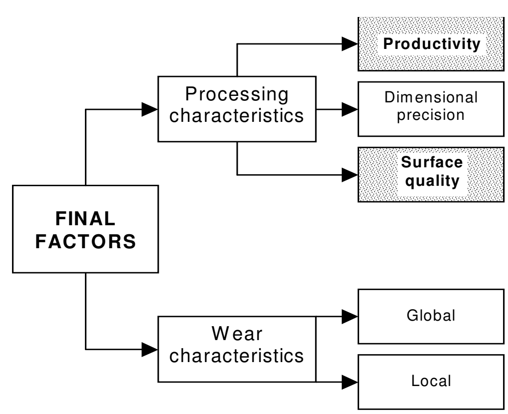

Fig.2 Final factors of the electrical erosion processing

These variables are determined starting from the final factors (productivity and roughness) specific to a given fabrication task. Fig.1 and fig.2 show the primary and final factors respectively.

2. CALCULATION ALGORITHM OF THE OPERATING CONDITIONS PARAMETERS, USING FUZZY SETS

The steps that need to be covered in the fuzzy sets based decisional process are described as follows.

Establishing the criteria according to which the processing parameters will be determined

These criteria make the evaluation criteria set:

$$C = \{C_1, C_2, ..., C_j, ..., C_m\} \qquad (1)$$

The particularity of the fuzzy set based procedure for determining the processing parameters is that several evaluation criteria may be taken into account at given moments. These criteria will be defined as *inputs* of the decisional system.

Defining the value range for each evaluation criterion

Each criterion has attached a variation range, containing the values specific to it. These value ranges are:

$$\begin{aligned} &C_1 : D_1 = [L_1^{inf}, L_1^{sup}] \\ &\vdots \\ &C_j : D_j = [L_j^{inf}, L_j^{sup}] \\ &\vdots \\ &C_m : D_m = [L_m^{inf}, L_m^{sup}] \end{aligned} \qquad (2)$$

where L_j^{inf}, L_j^{sup} are the superior and the inferior limit of the value range for criterion C_j, $j = \overline{1,m}$.

Defining the linguistic variable associated to each evaluation criterion

A linguistic variable is attached to each evaluation criterion. So criterion C_j will become the linguistic variable $C_j, j = \overline{1,m}$.

Establishing the linguistic degrees associated to each linguistic variable

The *linguistic degrees* or *linguistic terms* are defined for each linguistic variable. These will serve for a "vague" characterization of firm information. The linguistic degrees sets associated to each linguistic variable will be:

$$\begin{aligned} &C_1 : \quad GL_1^C = \{GL_{11}^C, GL_{12}^C, ..., GL_{1K}^C\} \\ &\vdots \\ &C_j : \quad GL_j^C = \{GL_{j1}^C, GL_{j2}^C, ..., GL_{jk}^C\} \\ &\vdots \\ &C_m : \quad GL_m^C = \{GL_{m1}^C, GL_{m2}^C, ..., GL_{mk}^C\} \end{aligned} \qquad (3)$$

Establishing the appurtenance functions associated to each linguistic degree; input variables

An appurtenance function is associated to each linguistic degree that correspond to a linguistic value:

$$\begin{aligned} &C_1 \rightarrow \quad GL_1^C \rightarrow FA_1^C = \{fa_{11}^C, fa_{12}^C, ..., fa_{1K}^C\} \\ &\vdots \\ &C_j \rightarrow \quad GL_j^C \rightarrow FA_j^C = \{fa_{j1}^C, fa_{j2}^C, ..., fa_{jK}^C\} \\ &\vdots \\ &C_m \rightarrow \quad GL_m^C \rightarrow FA_m^C = \{fa_{m1}^C, fa_{m2}^C, ..., fa_{mK}^C\} \end{aligned} \qquad (4)$$

Defining the output variables of the decisional process

The output variables of the decisional process will be the operating conditions parameters:

$$PRL = \{PRL_1, ..., PRL_i, ..., PRL_n\} \qquad (5)$$

Establishing the value ranges of the output variables

The value ranges of the output variables (processing parameters) are:

$$PRL_i = \{PRL_i^1, ..., PRL_i^j, ..., PRL_i^m\} \quad i = \overline{1,n} \qquad (6)$$

Defining the linguistic variable corresponding to the output variables

A *linguistic variable* is associated to each output variable. So the output variable PRL_i, $i = \overline{1,n}$ will become the linguistic variable PRL_i, $i = \overline{1,n}$.

Establishing the connecting method for various values of the appurtenance functions

The linguistic variables and degrees set, to which appurtenance functions are associated, characterize “vaguely” the firm values of the input variables and output values respectively. The *inference machine* is made of a set of rules as follows:

IF (premise) ***THEN*** (conclusion) (7)

Premise – the observed property that results after the connection of various linguistic degrees associated to the linguistic variables corresponding to the input variables, by means of procedures specific to the fuzzy sets theory; the **AND** connector was used in the case of the following ordonnance procedures.

Conclusion – the affirmed property, which will be expressed by linguistic degrees associated to the linguistic variables corresponding to the output values.

The rules base (inference machine) will look like this:

$$RIN_{in}: \textbf{\textit{IF}}\ (C_1 = GL^{C}_{l1}\ \textbf{\textit{AND}}\ \ldots\ \textbf{\textit{AND}}\ C_m = GL^{C}_{lm})\ \textbf{\textit{THEN}}\ (PRL_1 = PRL_1^{j_1})\ \ldots\ (PRL_i = PRL_i^{j_i})\ \ldots\ (PRL_n = PRL_n^{j_n}) \quad (8)$$

Establishing the de-fuzzification method

The chosen de-fuzzification method is the *effects cumulation* (*incremental method*), which is based on the following principles:

- The linguistic degrees corresponding to the input variables are chosen so that, each time, only one inference rule will be activated by one firm value (set of firm values) of the input;
- The linguistic degrees of the output linguistic variable are singleton-type, and to each linguistic degree is associated an increment of the output variable firm value according to the previous history:

$$u_{k+1} = u_k \pm [\Delta u_{in}]_k \quad (9)$$

where:

u_{k+1} - new value of output (moment *k*+1)

u_k - old value of output (moment *k*);

$[\Delta u_{in}]_k$ - increment associated to the active rule *i*.

In case there are several outputs, relation (9) will be applied for each one separately.

3. APPLYING OF THE OPERATING CONDITIONS PARAMETERS DETERMINATION SYSTEM ON THE ELER-01-GEP-50-F USING FUZZY SETS

A computerized command system for an electrical erosion processing machine was made, based on the fuzzy sets theory. The block-diagram of this system is shown in fig.3. The assurance of optimal processing parameters leads to obtaining the required roughness and increasing the productivity of the electrical erosion processing. The component systems will next be described as they were defined in the main diagram.

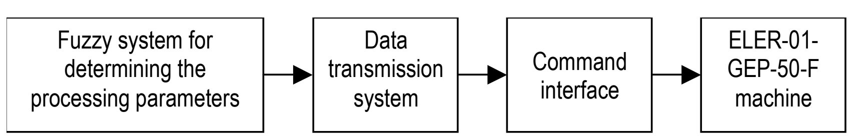

Fig.3. Block-diagram of the computerized command system.

The criteria according to which the processing parameters are determined are:

1. Roughness of the processed surface;
2. Productivity of the processing.

The variation ranges are:

Roughness: $C_1 : D_1 = 1 \div 25\ [\mu m]$

Productivity: $C_2 : D_2 = 0 \div 400\ [mm^3/min]$.

Linguistic variables associated to each evaluation criterion

The *Roughness* linguistic variable (noted RA) is associated to the *Roughness of the processed surface* criterion, and the *Productivity* linguistic variable (noted PROD) is associated to the *Productivity of the processing* criterion.

Linguistic degrees associated to each input linguistic variable

The linguistic degrees associated to each input linguistic variable are:

$$RA: \quad GL_1^{RA} = \{mf1;\ mf2;\ ...;\ mf7\}$$
$$PROD: \quad GL_2^{PROD} = \{mf1;\ mf2;\ ...;\ mf7\} \qquad (10)$$

Appurtenance functions associated to each linguistic degree; input variables

An *appurtenance function* is associated to each linguistic degree, corresponding to an input linguistic variable. These triangular-shaped functions are shown in fig.4.

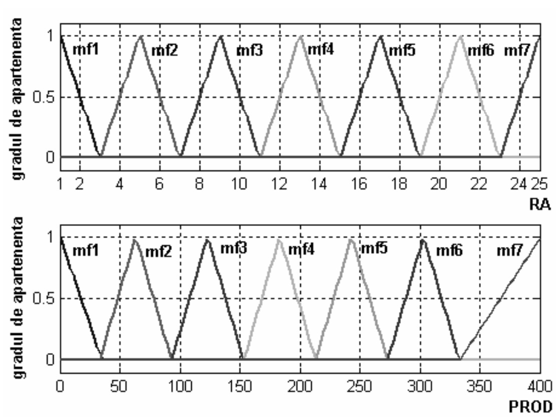

Fig.4. Appurtenance functions; input variables.

Decisional process output variables

The decisional process output variables are the next operating conditions parameters:

- Current intensity (I);
- Impulse time (TI);
- Pause time (TP).

That is:

$$\text{PRL} = \{\text{I}, \text{TI}, \text{TP}\} \qquad (11)$$

Establishing the value ranges of the output variables

The value ranges of the output variables (the processing parameters) are the following discrete values sets:

$$\text{I} \in \{3,6,12,15,18,24,27,30,37,40,46,50\} \quad [\text{A}]$$
$$\text{TI} \in \{2.5,4,6,8,12,24,48,95,190,420,900,1800\} \quad [\mu\text{s}] \qquad (12)$$
$$\text{TP} \in \{2.5,4,6,8,12,24,48,95,190,420,900,1800\} \quad [\mu\text{s}]$$

Linguistic variables corresponding to input variables

A *linguistic variable* is associated to each output variable. Thus:

- the *Current intensity* output variable becomes the *Intensity* linguistic variable (noted *I*);
- the *Impulse time* output variable becomes *Impulse time* linguistic variable (noted *TI*);
- the *Pause time* output variable becomes *Pause time* linguistic variable (noted *TP*);

12 singleton-type linguistic degrees are associated to these three linguistic variables corresponding to the input variables. Each linguistic degree has a corresponding value in the values set of the output value:

$$I: \quad GL_1^{I} = \{mf1;\ mf2;\ ...;\ mf12\}$$
$$TI: \quad GL_2^{TI} = \{mf1;\ mf2;\ ...;\ mf12\} \qquad 13)$$
$$TP: \quad GL_3^{TP} = \{mf1;\ mf2;\ ...;\ mf12\}$$

Connecting method for various values of the appurtenance functions

The *inference machine* is formed of a set of 49 rules as follows:

1. If (RA is mf1) and (PROD is mf1) then (I is mf1)(TP is mf12)(TI is mf1) (1)
2. If (RA is mf1) and (PROD is mf2) then (I is mf1)(TP is mf11)(TI is mf2) (1)

………………………………………………….

23. If (RA is mf4) and (PROD is mf2) then (I is mf5)(TP is mf8)(TI is mf5) (1)
24. If (RA is mf4) and (PROD is mf3) then (I is mf6)(TP is mf7)(TI is mf6) (1)

………………………………………………….

48. If (RA is mf7) and (PROD is mf6) then (I is mf12)(TP is mf2)(TI is mf12) (1)
49. If (RA is mf7) and (PROD is mf7) then (I is mf12)(TP is mf1)(TI is mf12) (1)

Implementing the fuzzy sets based decisional system

The decisional system implemented in Fuzzy Logic Toolbox of MATLAB® is shown in fig.5, the variation of current intensity versus roughness and productivity in fig.6 and the inference rules in fig.7.

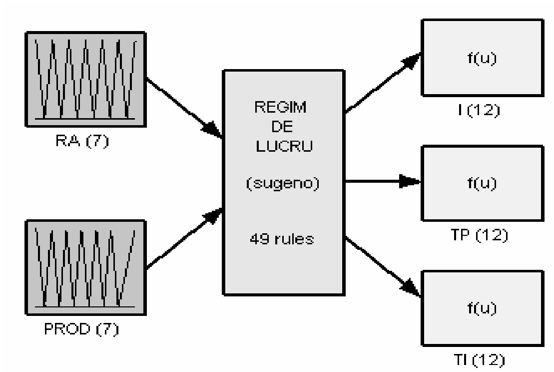

Fig.5. REGIM DE LUCRU fuzzy sets based decisional system

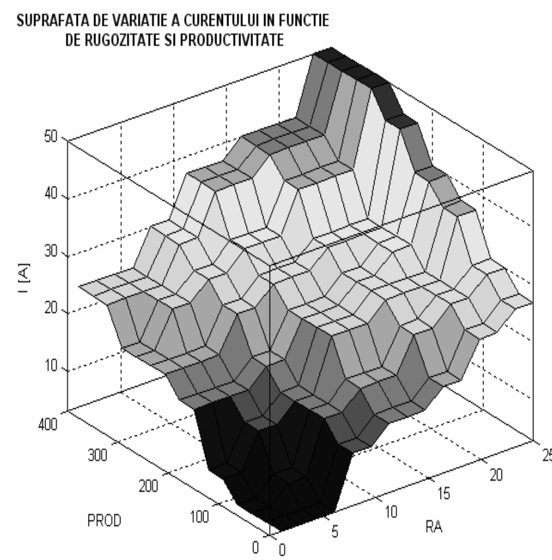

Fig.6. Variation of current intensity I=f(PROD,RA); I – current intensity [A], PROD – productivity [mm^3/min], RA – roughness [µm]

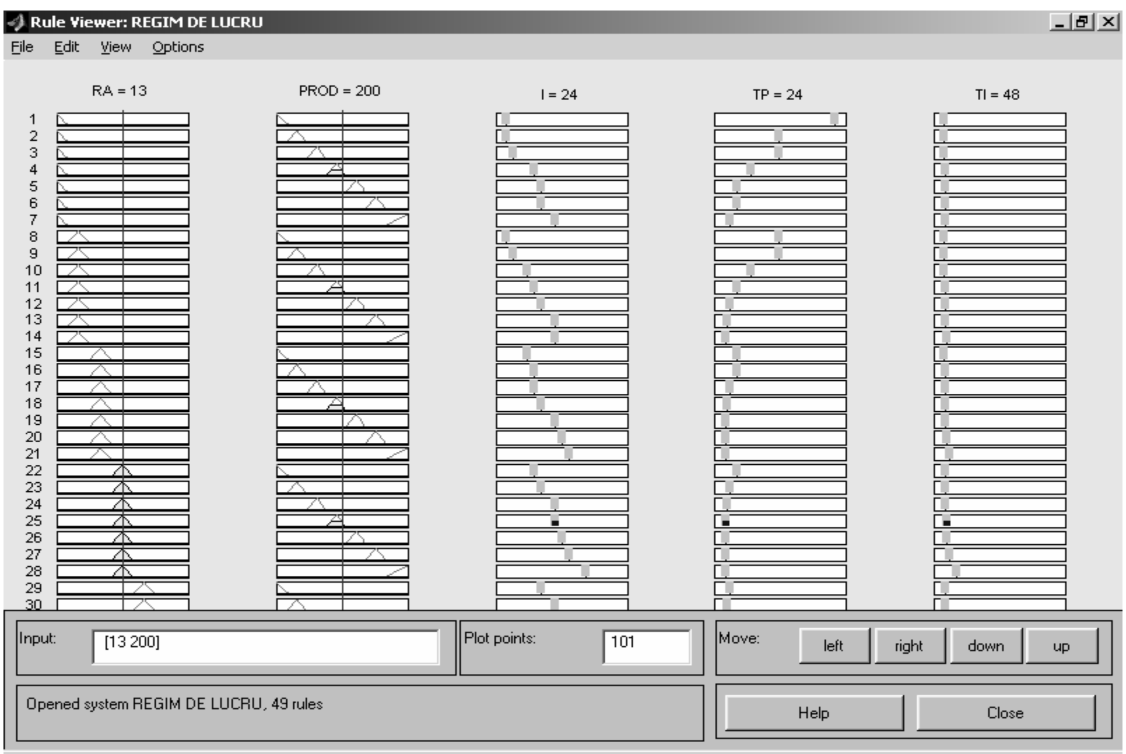

Fig.7. Inference rules

A set of programs has been elaborated in MATLAB® for the determination of the processing parameters. These programs allow:

1. Introduction of the firm values of the input variables:
- Roughness [µm];
- Productivity [mm^3/min].

2. Determination of the values of processing parameters by means of the decisional system *REGIM DE LUCRU.fis*
3. Setting and transmitting the values of the processing parameters to ELER-01-GEP-50-F machine.

The graphic interface, generated by the main program *INTER* is shown in fig.8.

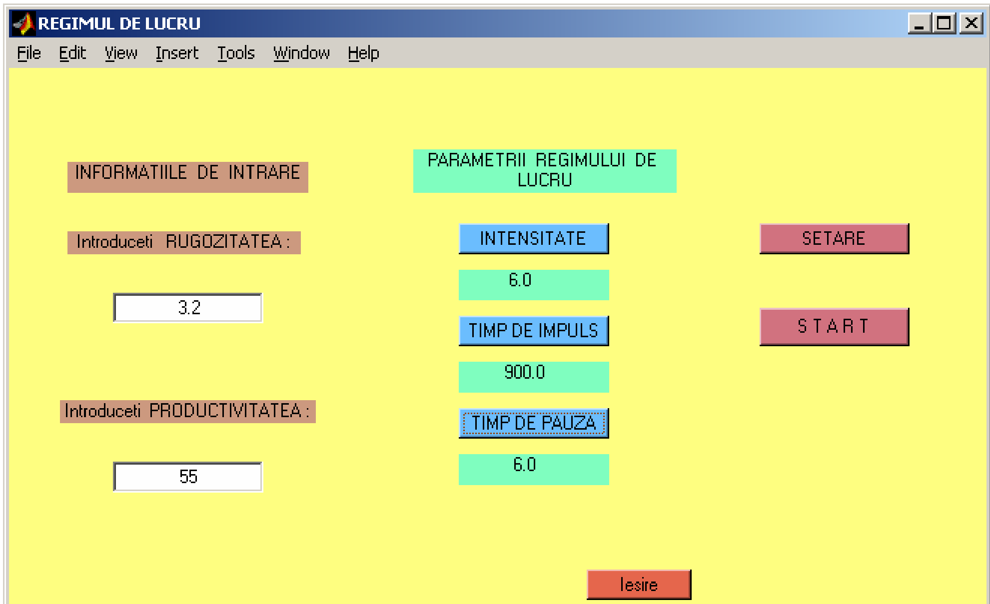

Fig.8. Graphic interface for processing parameters determination

4. CONCLUSIONS

The usage of fuzzy sets offers a new perspective for the optimization of electrical erosion processing technologies. The fuzzy sets based algorithm gives a general determination procedure of the processing parameters, starting from the optimization criteria. Applying the algorithm on the electrical erosion processing by ELER-01-GEP-50-F allows the determination of the processing parameters (current intensity *I*, impulse time T_i, pause time T_p), starting from the primary factors (productivity and surface quality). Implementing this procedure on computer and integrating it with ELER-01-GEP-50-F machine opens the possibility for making a flexible electrical erosion processing cell.

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