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DEPARTMENT OF MECHANICAL ENGINEERING

Building of rules base for fuzzy-logic control of the ECDM process

EXPERIENTIAL LEARNING REPORT

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(Autonomous Institution affiliated to VTU, Belagavi)
Department of Computer Science and Engineering

CERTIFICATE

Certified that the Assignment entitled **"Building of rules base for fuzzy-logic control of the ECDM process"** has been carried out by **Mr. Rithwik Shankar Raj** USN: **1RV19ME087**, a bonafide student of **R.V. College of Engineering, Bengaluru** in partial fulfilment for the award of **Bachelor of Engineering** in **Mechanical Engineering** of the **R V College of Engineering (**Autonomous Institution affiliated to VTU, Belagavi**)** during the year **2022-2023**. It is certified that all corrections/suggestions indicated for internal assessment have been incorporated in the report deposited in the departmental library. The Assignment report has been approved as it satisfies the academic requirement in respect of Assignment work prescribed for the said degree.

Name of the Faculty	**Signature with Date**
Prof. Jinka Ranganayakulu	________________

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ABSTRACT

‘‘In ECDM process, generally a cumulative effect of discharges striking the workpiece surface and electrochemical dissolution process are observed. This process is described mainly by the current–voltage dependences. This paper presents, the simplified model for estimation current of electrochemical dissolution and electrodischarge machining in the ECDM process. Basing on this model there is also presented an attempt of adapting fuzzy-logic controller for ECDM process. Paper contains also simplified model of the control system used for simulations.’’

‘‘The simulation has been carried out using MATLAB and SIMULINK. The Fuzzy logic-based controller described in the model has been implemented using the Fuzzy logic toolbox in MATLAB. The controller for the ECDM process had been replicated using SIMULINK module.’’

1: Introduction

Application of electrochemical machining gives possibility to get the machined surface with good quality, when there is high efficiency and lack of electrode wear. But we can get the worse accuracy in comparison to the machining result, when the electro discharge machining is used. It is expected that, when the electrochemical machining and electro discharge machining are used at the same time, it is possible to change the accuracy, efficiency and properties of the machined surface layer in higher range than in each individual process.

Combining these two methods together makes it possible, in comparison to classical EDM, decrease of electrode tool wear and increase of machining metal removal rate. Application of this hybrid method will be very useful for micromachining.

ECDM method gives good results especially in case when elements, made of special steels or ceramics, are machined, i.e., for machining of materials with special properties and difficult for machining with conventional methods. Electrical discharges associated with the electrochemical dissolution process cause material removal and can be effectively used for machining of conducting materials. It is assumed that this process can be also effective for machining of non-conducting materials.

2: Problem Formulation

According to the rapid development of new materials, recent research in the field of machining processes is aimed at investigations and optimization of hybrid machining processes. One of the hybrid processes is electrochemical electro discharge machining (ECDM) process. The combination of different physicochemical influences at the same moment during machining of special and composite materials gives fruitful advantages. These are: increase of the machining metal removal rate, accuracy and quality of machined surfaces. When the material is removed with using simultaneous electro discharge processes and electrochemical dissolution, we can say that the machining was with application of electrochemical machining intensified with electro discharge process.

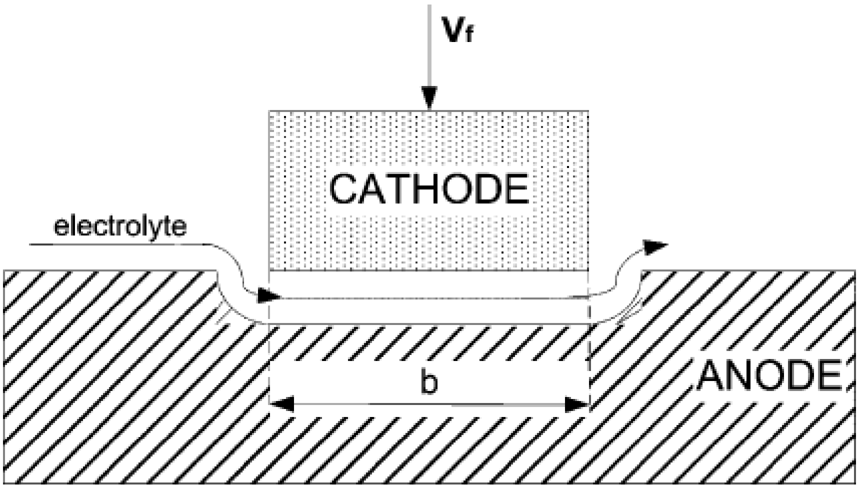


Figure 1: Schematic of ECDM model

During ECDM process, transfer from the area of electrochemical machining to the area of electro discharge machining is observed. Researchers observed the different mechanisms of discharges. These mechanisms depend on the electrolyte conductivity, pulse voltage and pulse time. For our model, we assumed that EDM and ECM processes will take place at the same time in the machining area but at the different areas. We assume that the machining process takes place in the interelectrode gap with predicted length b (see Fig. 1). The electrolyte inlet is along gap from the side. For the simplified model, we assume that the electrochemical dissolution process takes place at the one area of the gap and the electro discharge machining—at the other parts of the gap. The reason for such arrangement is the creation of the vapor—gas layer in area of electrical discharges. The thickness of interelectrode gap has the greatest influence on the share of these two processes in considered hybrid machining method. The increase of gap thickness disables creation of electrical discharges, but enables electrochemical dissolution to occur.

For the determined voltage U and for small feed rate v_f , when the gap thickness is $s > s_{critical}$, the electrochemical dissolution takes place. When the feed rate increases and gap thickness decreases and is near to $s_{critical}$, the discharges are observed and simultaneously with electrochemical dissolution there appears electro discharge machining. The metal removal rate and surface quality depend on the share of these different machining process. Very important factor for modelling the ECDM process is setting the temperature distribution T in the interelectrode gap in order to estimate the place, where the electrolyte boiling temperature may be reached and could be created the vapor layer. Because, this estimation is very difficult, so we assumed for our simply model that the electrolyte temperature and its properties are constant in machining area, and also there are no empty and short-circuit pulses. In considered model, the most important parameters are: electrode feed rate v_f and current I.

For the developed ECDM model, we take into account the process scheme presented in Fig. 1. For presented above conditions and scheme of machining we can estimate the current according to the following equations:

$$I_{\mathrm{ECM}} = A_{\mathrm{ECM}} \frac{v_{\mathrm{f}}}{k_{\mathrm{ECM}}} \tag{1}$$

$$I_{\mathrm{EDM}} = (Hb - A_{\mathrm{ECM}}) \frac{v_{\mathrm{f}}}{k_{\mathrm{EDM}}} \tag{2}$$

$$V_{\mathrm{w}} = bHv_{\mathrm{f}} \tag{3}$$

$$I = I_{\mathrm{ECM}} + I_{\mathrm{EDM}} \tag{4}$$

$$I = A_{\mathrm{ECM}} v_{\mathrm{f}} \left[\frac{1}{k_{\mathrm{ECM}}} - \frac{1}{k_{\mathrm{EDM}}} \right] + \frac{V_{\mathrm{w}}}{k_{\mathrm{EDM}}} \tag{5}$$

$$I = f(v_f) \tag{6}$$

$$v_f = \frac{I_{ECM}}{A_{ECM}[(1/k_{ECM}) - (1/k_{EDM})]} \tag{7}$$

where I_{ECM} is the current for electrochemical process, I_{EDM} the current for electro discharge process, H the electrode tool width, b the electrode tool length, v_f the electrode feed rate, AECM the surface of electrochemical dissolution, k_{ECM} the factor for estimation of electrochemical dissolution rate, k_{EDM} the factor for estimation of electro discharge machining rate, and V_w is the metal removal rate, $k_{EDM} > k_{ECM}$..

The relation (7) gives us information for conditions- especially electrode feed rate v_f, which are necessary for realization ECDM process. The above model helps us to understand the phenomena occurring in ECDM process.

3: Fuzzy Logic Control

Application of fuzzy-logic to the controllers enables to change from the quantitative way of process description to the quality side. It means that it is possible to use more efficiently the knowledge of people who explored and were using the process. The basic scheme of the control system based on fuzzy-logic is shown in Fig. 2.

In our case, we decided to take into account as, “inputs” to our controller, two parameters measured during process: current and voltage. Voltage, especially rapid and unexpected drops of voltage, is very important factor in detecting and avoiding contact between two electrodes. Current plays its important role in material removal rate (speed of the process) and in the surface quality after machining (too many sparks generate poor surface). Based on the above-mentioned observations, we decided the output signal from controller to be responsible for generating proper movement of the electrode, by controlling it is velocity. In further considerations it is shown in percentage of the full range (100%—i.e., 2 mm/min towards workpiece; 100%—i.e., 2 mm/min up from the workpiece.

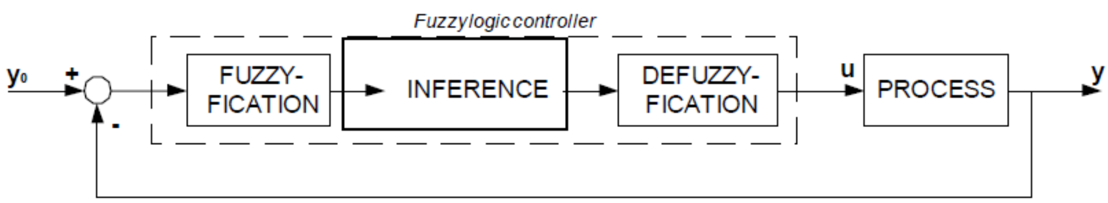


Figure 2: Block scheme of Fuzzy Logic Controller

First step was to divide areas of all parameters into proper smaller ranges. For each factor, there were also prepared membership functions. In our case, when vf = f (U, I), it looked as shown in Fig. 3. The membership function (ZO) from Fig. 3c has different shape than other ZO functions. It results from the fact that in some cases it is not necessary to force the movement of the electrode. In each case, when the signal appears in this range it will be filtered and sent as zero to the drive system. The other reason is that there would be no rule generated, either run, in case of crossing N and P functions (0).

4: Modelling and Rule Base

In this stage, based on the results from previous experiments and for assumption that exists ideal ECDM process, there was an attempt to create the rules base. As we have two input variables and each has three membership functions, it is necessary to create nine rules. For each rule the membership rank of input variable to various ranges was checked. Then the one of maximal value was chosen, according to the maximum rule:

$$\{U(1)[\max : 0.7 \text{ in } N],\ I(1)[\max : 0.9 \text{ in } P];\ V(1)[\max : 0.6 \text{ in } P]\}$$
$$\Rightarrow R^1 : \textbf{IF } (U(1) \text{ is } N) \textbf{ AND } (I(1) \text{ is } P) \textbf{ THEN } (V(1) \text{ is } P)$$

For all contrary rules, the membership ranks were multiplied, and the rule of highest multiplication value was chosen.

U \ I	N	ZO	P
N	ZO	N	N
ZO	P	ZO	ZO
P	P	P	ZO

The last stage of creation of fuzzy-logic controller is defuzzification. The aim of this is to prepare “sharp” numerical value of control signal that could be applied to the drive system. In this case, method of Center average defuzzification was used.

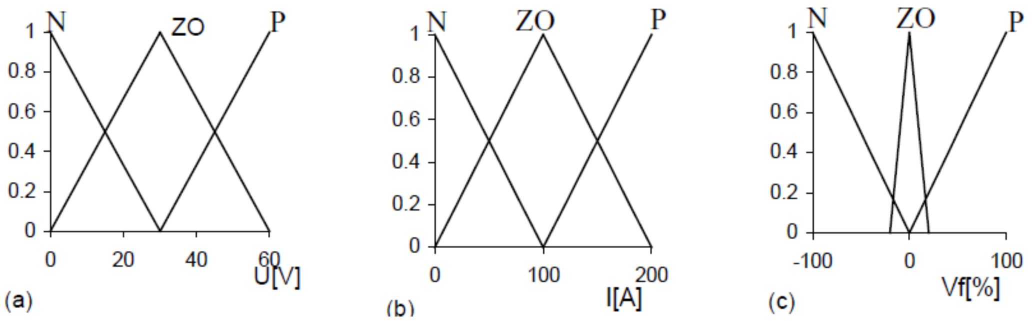


Figure 3:Membership functions of input and output variables

5: Rule Base Creation Algorithm

The workflow of the algorithm used for the creation of the rule base is as shown:

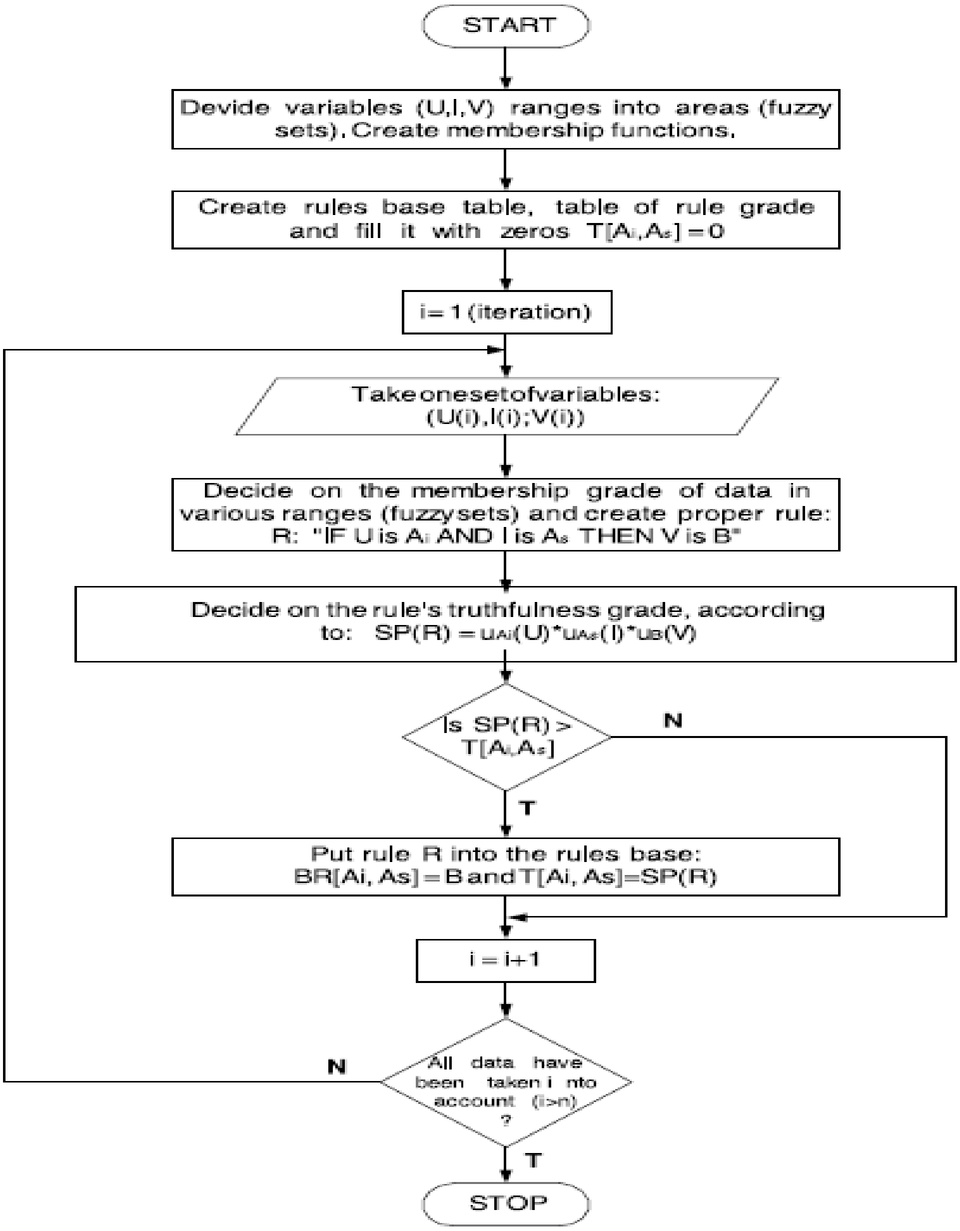


Figure 4: Flowchart for rule base creation

6: Application of FLC

Simulation tests of the system have been performed using MATLAB environment. Test of the controller were done with the toolbox for projecting and testing the fuzzy-logic based on systems—Fuzzy-Logic Toolbox, and tool for modeling and simulations of dynamic system—Simulink.

In our model of the control system, we used the mathematical–physical model of the ECDM process described earlier in the paper. As input voltage we generated pulse signal of amplitude 20V and pulse on time 1 ms, pulse off time 1 ms. The presented system contains model of the process for 6% water solution of sodium nitride.

Temperature of working fluid at its inlet to the machining gap was considered to be 25 ◦C. Membership functions and other parameters of the model have been set up empirically. Main aim of the controller was to provide such value of feed rate to react in one step to sudden changes of voltage and current generated during ECDM process.

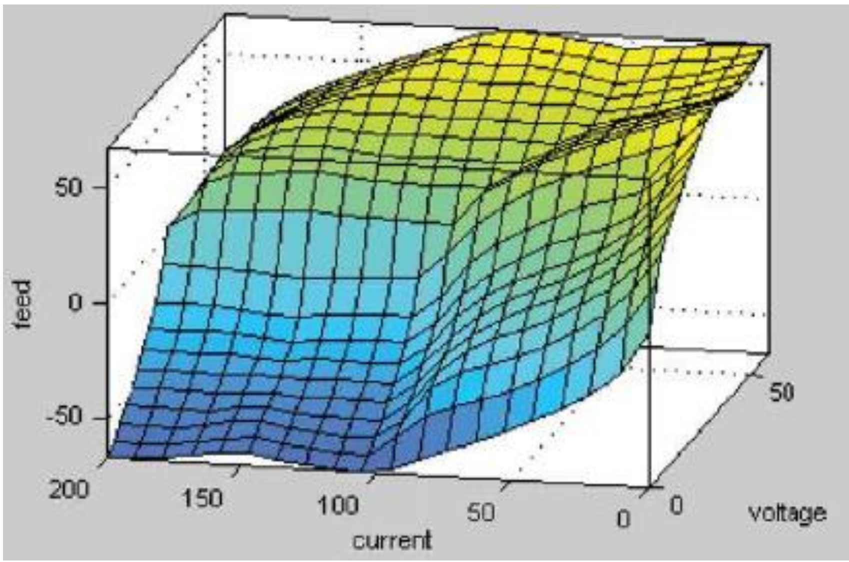


Figure 5: Control surface of FLC

As voltage in the means of controller authors understand the difference between voltage from generator and value of process voltage. Considered model does not take into account noise signals generated during real machining process. Control signals have been generated by the controller basing on the rules base presented above. Fuzzy-logic toolbox prepared control surface, which is presented in Fig. 5.

Fig. 6 shows an example curve of voltage applied to the process, current generated by the model and feed rate of the electrode. Electrode movement results from the fuzzy-logic controller reaction to the process parameters appearing at its input. One can see that the feed rate of electrode is being regulated just after change of current. This way of control of the process variables will result in improvement of the ECDM process especially in the matter of machining quality and accuracy.

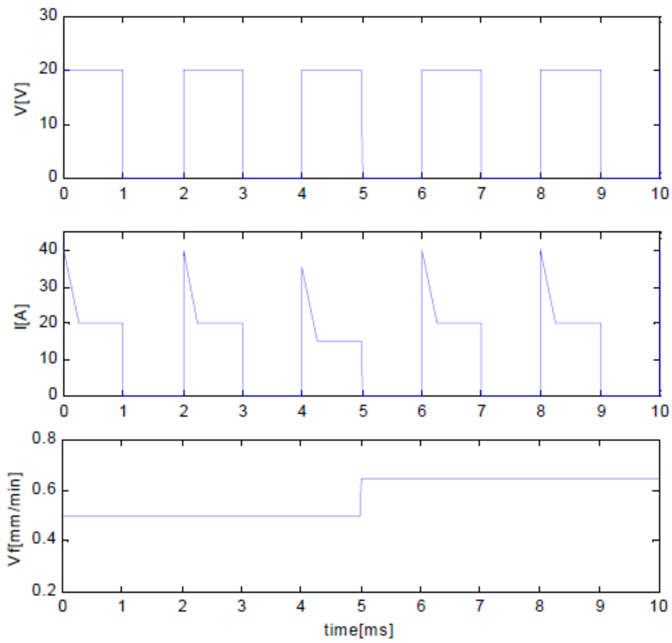


Figure 6: Output of FLC

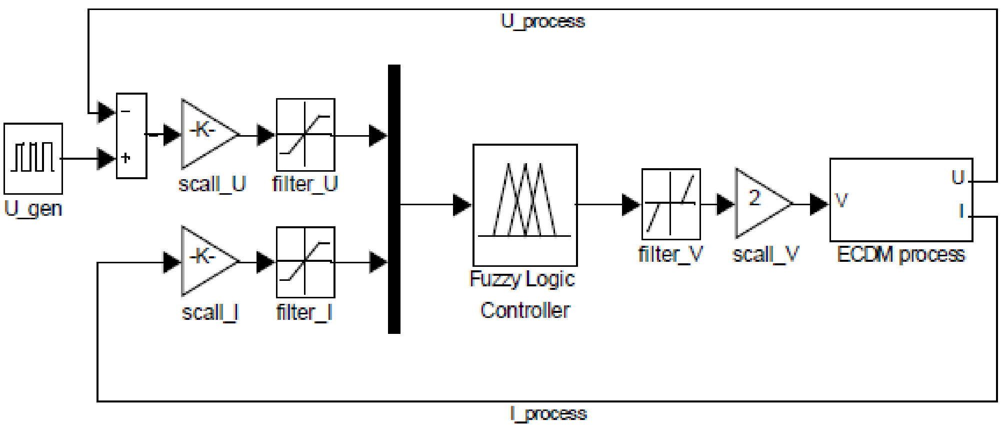
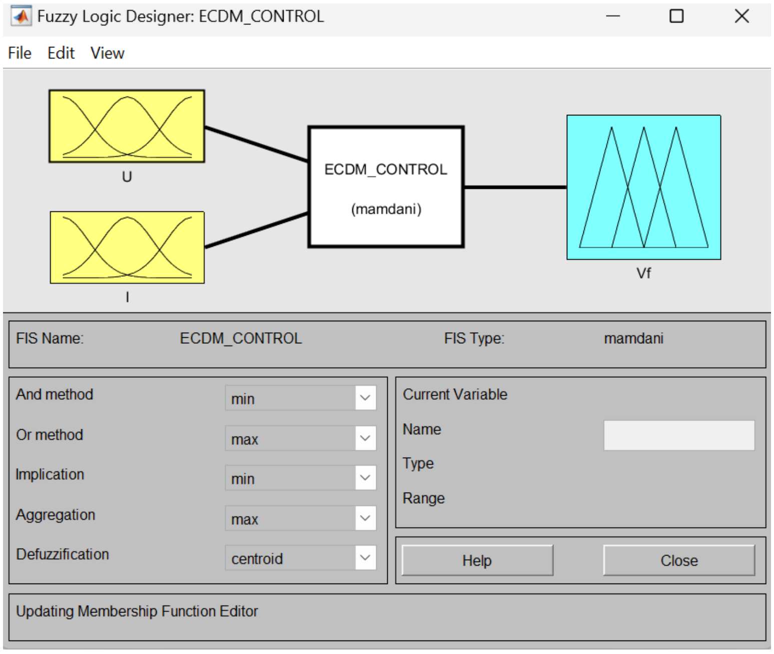


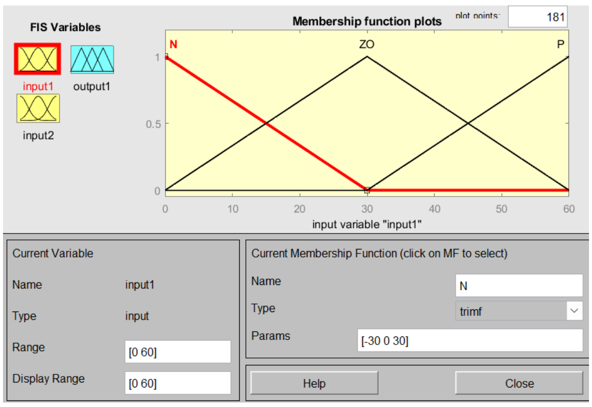
Figure 7:Simulink model of ECDM process

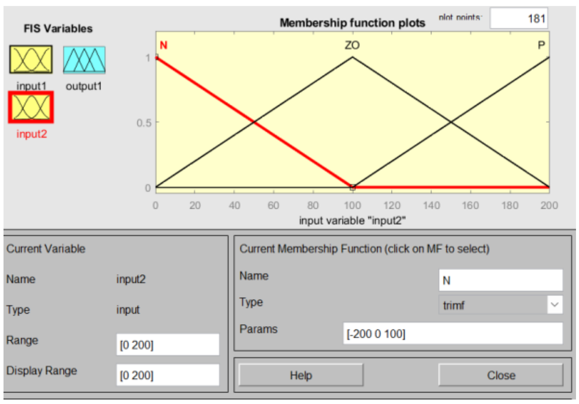
IMPLEMENTATION IN MATLAB FUZZY LOGIC TOOLBOX

Based on the membership functions the system has been implemented in Fuzzy logic toolbox of MATLAB.

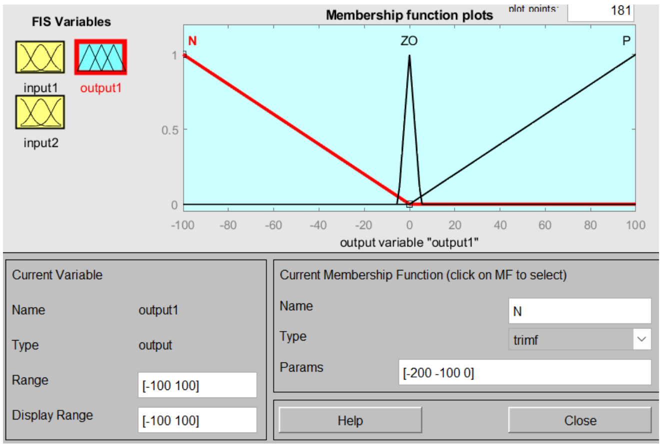


The input membership functions are defined as follows:

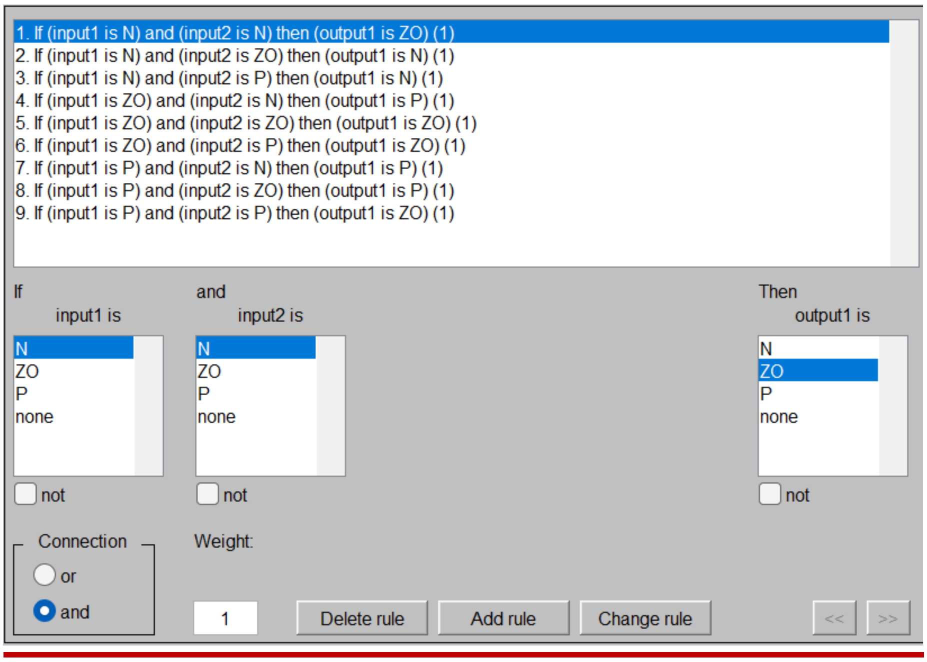




The output membership function is defined as follows:



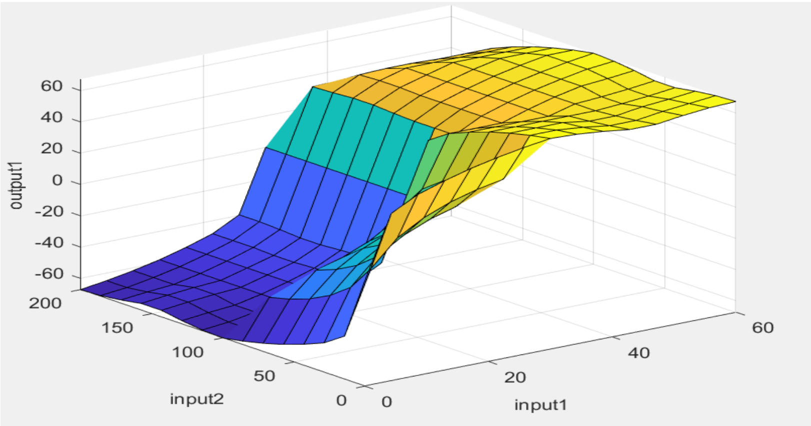
The rule base is defined as follows:



The script to generate the control surface for the inputs of voltage and current as 20 V and 40 A is as follows:

```
fis=readfis('ECDM_CONTROL');
output=evalfis(fis,[20,40] )
gensurf(fis)
```

The control surface is as follows:



7: Conclusion

Despite the fact that this process is still a matter of investigations, ECDM is gathering large number of commercial implementations. Especially, in the industry requiring high efficiency and accuracy of the machining. This method could be used in electronics, aviation and medical (surgery) industries.

Tests of the fuzzy-logic controller, performed using the model stand of the ECDM process. Next stages, which are vital in the field of controller application, are: verification and improvement of the process model; searching for new/better membership functions and fuzzy sets used in the rules base of the fuzzy-logic system.

Also system used for simulations of the controller will be improved by adding subsystems responsible for noises generation and filtration of the signals important for the process. Fuzzy-logic and especially adaptive fuzzy-logic control system may help in reducing the number of microcracks and surface roughness parameter. This way of process control may also benefit from increase of metal removal rate for this process.

Practical application of the fuzzy-logic controller at the real machine may occur to be difficult, as it is very hard to make fast measurement and analysis of current during machining process.

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