Simulation of Hydraulic Generators with Fuzzy Logic

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Abstract

The goal of this paparwork is to simulating a fuzzy logic system used in Matlab for modeling functional characteristic of hydraulic generators type centrifugal pump.

Key words: *simulation, fuzzy logic, centrifugal pump.*

Toolbox Software Fuzzy Logic

Toolbox software Fuzzy Logic used is from Matlab simulation program. Building a fuzzy logic system in Matlab is simple thanks to the graphical interface through which users can communicate with the environment Matlab simulation. This interface allows the construction and graphical analysis of the fuzzy logic system, using the five dedicated graphical tools that form part of the Matlab fuzzy logic:

1. Editor fuzzy logic system called **FIS Editor** (Fuzzy Inference System Editor);

2. Editor membership functions, the fuzzy sets over input and output variables of fuzzy logic system, called the **Membership Function Editor**;

3. Editor fuzzy rules, which will form the basis of rules of the system fuzzy logic, called **Rule Editor**;

4. Viewing window of the rules, you can see the degree of activation of each rule and the result (set of fuzzy output) given every rule of rules for a particular tranche of the entry value set by the user, this window appears under the name **Rule Viewer**;

5. Window surface view of the system input-output fuzzy logic, output dependence graph showing the fuzzy logic system for fuzzy logic system inputs, caused by the operation of fuzzy logic, the window appears under the name **Surface Viewer** (Area control system).

The five graphical tools are related, in that an amendment to the fuzzy logic system made in editing one of the windows will affect the other windows.

Further, methods of analysis will be presented to officials with fuzzy logic systems using Matlab simulation environment for application development with fuzzy logic for centrifugal pumps.

Designing a Fuzzy Logic System in Matlab

To begin designing a fuzzy logic system, first determine the experimental measurements (table 1) and will need to set up sets of input and output. Also, it will take the chose components of system with fuzzy logic.

Table 1. Experimental data

$p_{rx} \cdot 10^5$	$p_{ax} \cdot 10^5$	n_x	$Q_x \cdot 10^{-3}$	H_x
Pa	Pa	rad/s	$m^3/_s$	mcl
3.70	0.30	180	0.00	34.0
3.40	0.25	180	4.40	31.5
3.10	0.25	180	5.40	28.5
2.80	0.25	180	6.30	25.5
2.50	0.20	181	7.10	23.0
2.20	0.20	181	7.70	20.0
2.00	0.15	183	8.30	18.5
1.80	0.15	183	8.90	16.5
1.60	0.10	184	9.50	15.0
1.50	0.10	184	10.00	14.0
1.40	0.10	184	10.70	13.0
1.20	0.10	185	11.00	11.0
1.10	0.10	188	11.10	10.0
1.00	0.10	188	11.20	9.0
0.90	0.10	188	11.25	8.0
0.80	0.10	188	11.30	7.0

a. Its open package with fuzzy logic analysis by fuzzy startup command in Matlab program.

b. Its build the model editor window *Fis*. Here its define entry, exit, inference mechanism, the relationship of implication, aggregation and defuzzyfication (figure 1).
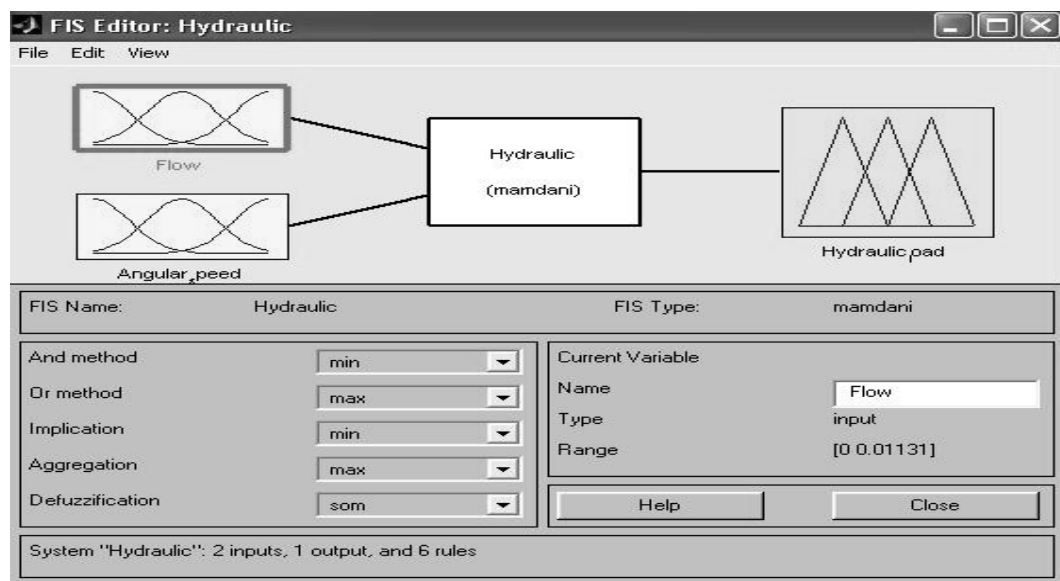
Fig. 1. Fis Editor.

You can change the operations used in the deductive process:

- AND allow the selection method used mathematical expression for the operator AND from the premise of fuzzy rule: it can be minutes or prod (product), and the default is min;
- The method OR allows selection of the mathematical expression used for the OR operator, which is the default operator linking rules in fuzzy rule base: this could be max or evidence (or probability), and the default is max;
- Implication defines the operation used to express the relationship between the fuzzy implication and consequence of each rule premise: it can be min or prod, and the default is min;

Implication relationship formula used for mathematical description of each rule in the fuzzy rule base is **min**, type **Mamdani** (figure 1).

- Aggregation defines the operation used to obtain partial conclusions, to get the response representing fuzzy logic system to a given value of the entry: it can be **max**, **sum** (algebraic sum) or **sample**, and the default is **max** (figure 2);
- Defuzzification defines the defuzzification method used: it can be: **centroid**, **bisector** (bisector area), **lom** (largest of maximum), **mom** (middle of maximum) or **som** (smallest of maximum).

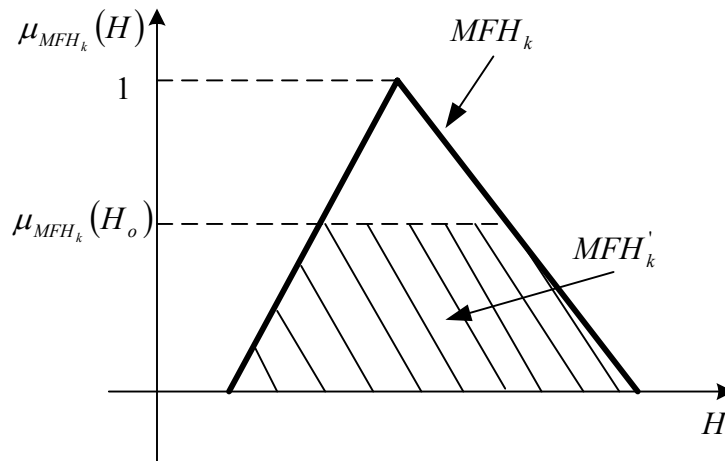Operation or inference mechanism used paper is **max-min** type (figure 2).

Fig. 2. Getting the partial conclusions from k fuzzy rules.

The formula to evaluates the output of every fuzzy rule is fuzzy R_k:

$$\mu_{MFH_k'}(H) = max_{Q,\omega} \, min\left[\mu_{MFH_0}(Q,\omega), min\left(\mu_{MFQ_0\omega_0}(Q,\omega), \mu_{MFH_0}(H)\right)\right] \qquad (1)$$

Where MFH_k' fuzzy output is usually generated R_k or partial conclusion fuzzy logic system.

Aggregated partial conclusions MFH_k', the rules of the nine fuzzy rule base is **max**.

$$\mu_{MFH'}(H) = max_k \mu_{MFH_k'}(H) \qquad (2)$$

where $MFH' = VMFH'_k$ is meeting all the crowds MFH'_k.

c. Its edit the corresponding inputs and output functions by setting the type of variation, the range of variation and number of features that will characterize each variable (figure 3).
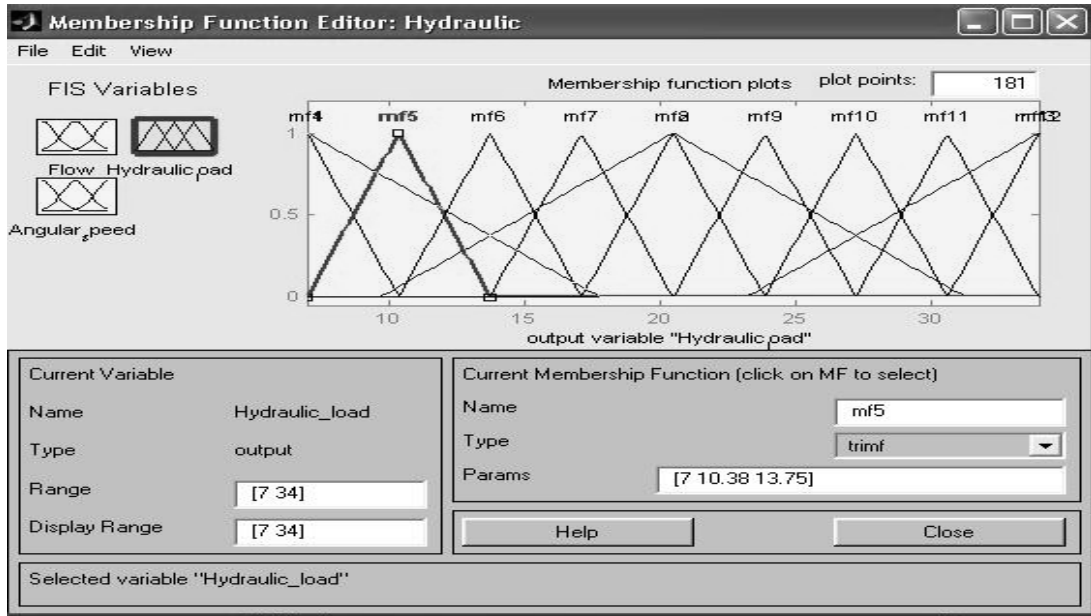

Fig. 3. Edit window of the FIS variables.

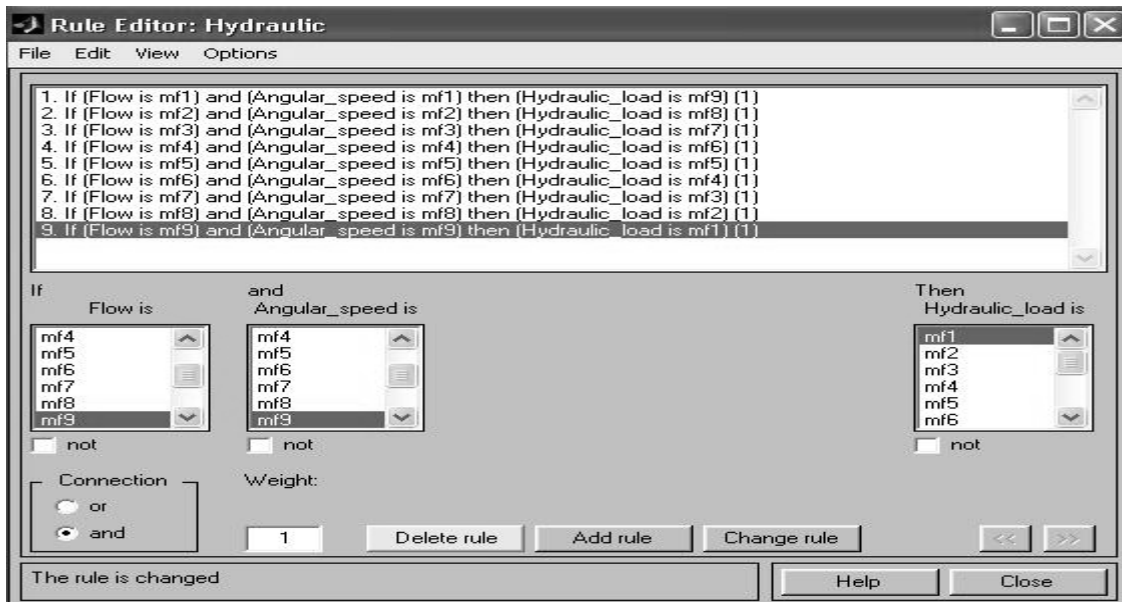d. It will devise rules that establish relationships between fuzzy sets, fuzzy input and fuzzy output (figure 4).

Fig. 4. Rule editor between fuzzy inputs an output.

We can be observed the partial conclusion $MFH_k^{'}$ 'for k rules of fuzzy rule base. (figure 5) and the general conclusion can be seen graphically in figure 6.
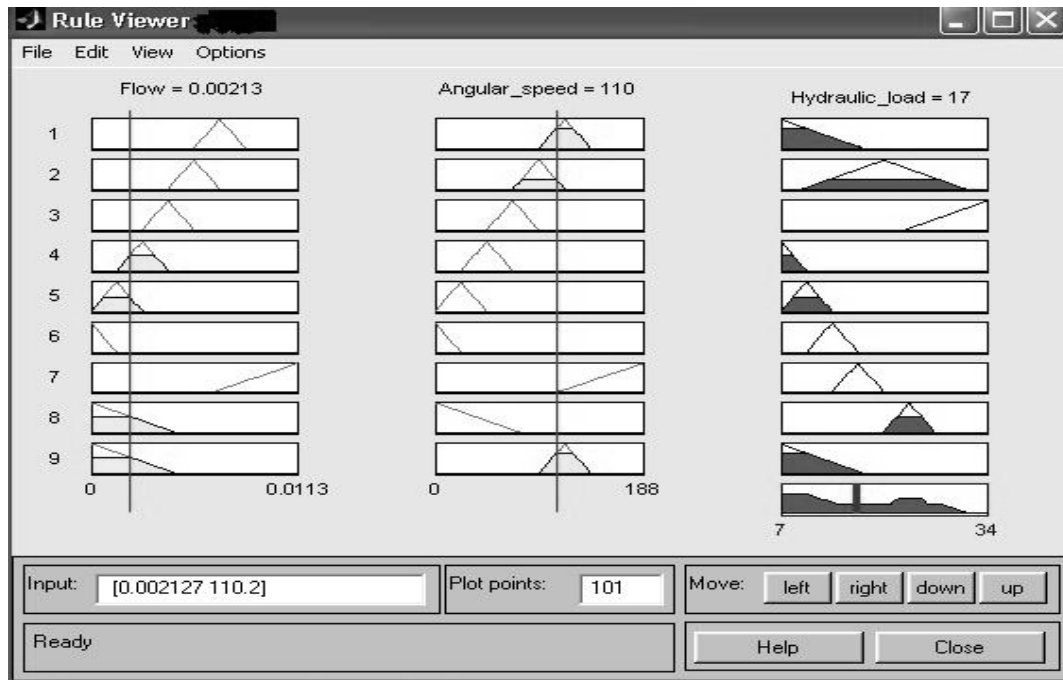

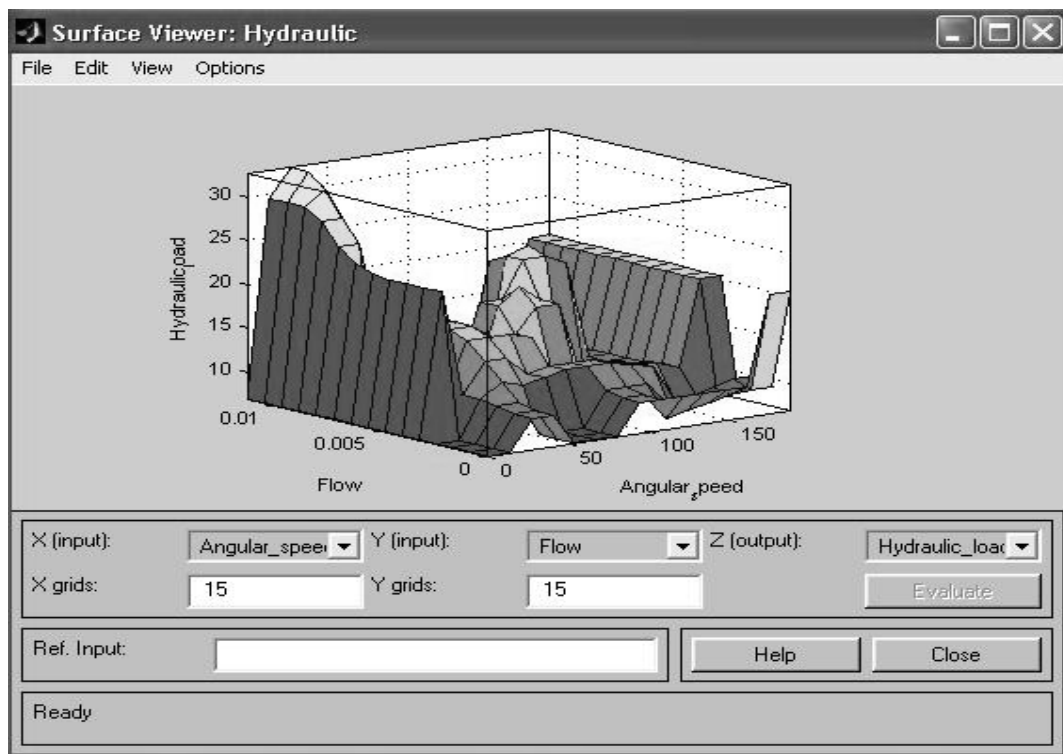**Fig. 5**. Rule viewer of partial conclusions.

Fig. 6. Surface viewer of the final conclusion.

Conclusions

- ○ System generated fuzzy knowledge incorporates predefined (experimentally obtained data) based on rules;
- ○ The rules that establish relationships between fuzzy sets, fuzzy input and fuzzy output are interpretable, if-then type;
- ○ Implementation - build input, output and setting the rules - is relatively simple, and knowledge / information are available at any time.

References

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Simularea generatoarelor hidraulice cu logica fuzzy

Rezumat

Scopul lucrării este de a simula un sistem cu logica fuzzy în Matlab folosit pentru modelarea caracteristicii funcţionale a generatoarelor hidraulice de tip pompă centrifugă. S-au definit variabilele de intrare şi de ieşire prin stabilirea operaţiilor din procesul de inferenţă (în editorul FIS). S-au stabilit, pentru fiecare variabilă în parte, domeniul de variaţiei şi tipul acesteia, s-au stabilit regulile de generare a concluziilor parţiale şi a concluziei generale şi s-a vizualizat răspunsul sistemului cu logica fuzzy.