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Fuzzy Logic System for Modeling Functional Characteristic of Hydraulic Generators

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Abstract

Aim of the study is to design a fuzzy logic system used in Matlab for modeling functional characteristic of type centrifugal pump hydraulic generators.

Key words: *fuzzy logic, functional characteristic, centrifugal pump.*

The Mathematical Model

Hydraulic machinery, hydraulic generators are used to transport fluid by transforming kinetic mechanics energy provided by a motor on hydraulic power. Functional characteristics (figure 1) of the hydraulic generator is correlation between functional parameters pressure p (hydraulic load H), flow Q and velocity ω.

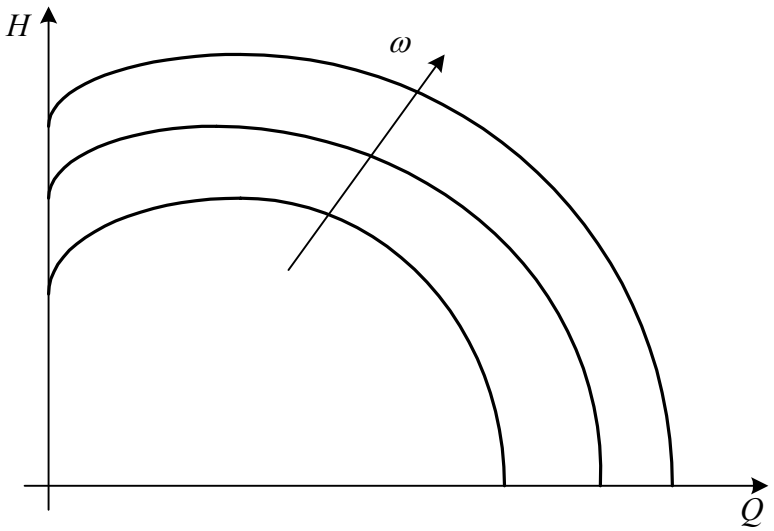

Fig. 1. Functional characteristics of the hydraulic generator.

Experimental measurements are performed to determine the characteristic functional bench shown in figure 2. The stand is equipped with a multi-storey centrifugal pump that circulated water.

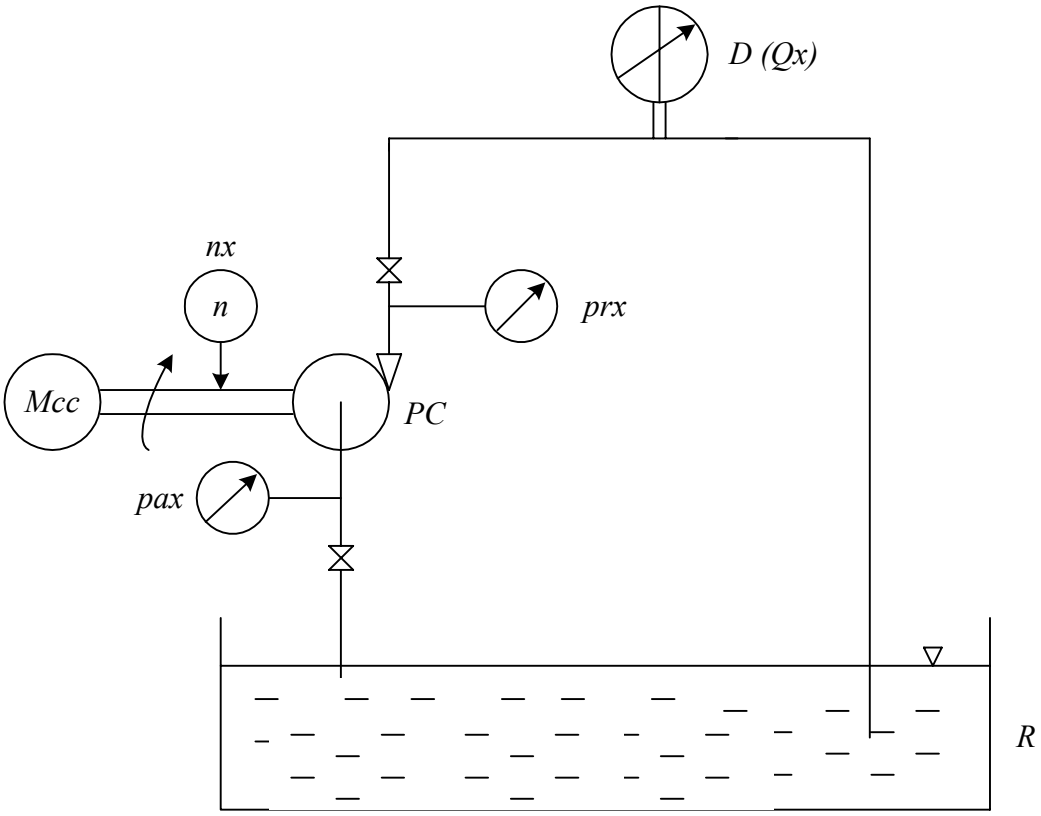

Fig. 2. The stand is equipped with a multi-storey centrifugal pump.
Mcc - DC electric motor, *PC* - centrifugal pump multi-storey, *R* - reservoir,
D - diaphragm for measuring flow, *n* - tachometer.

Algorithm to determine the hydraulic load is:

$$H_x = \frac{p_{rx} - p_{ax}}{\rho g} \tag{1}$$

where: H_x is hydraulic load, [mcl];

p_{rx} - repression pressure centrifugal pump, [Pa];

p_{ax} - centrifugal pump inlet pressure, [Pa];

ρ - water density [kg/m^3];

g – gravitational acceleration [m/s^2].

The Q_x flow, suction pressures and discharge p_{ax}, p_{rx} and *nx* speed centrifugal pump are measured on the stand.

Since the functionality of the centrifugal pump is a graphic dependent $H_x = f(Q_x)$ can be represented approximately as analytical, we can design a fuzzy logic system in which flow Q_x and velocity ω_x system are inputs and output load is H_x so:

$$\left|\hat{H}_x - f(Q_x)\right| \to 0 \tag{2}$$

Fuzzy Logic System for Modeling Feature $H_x=f(Q_x)$ Centrifugal Pump

Fuzzy logic system components used for modeling the functional characteristic $H_x = f(Q_x)$ of the centrifugal pump are:

a. fuzzy sets entry, noted MFQ_k (fuzzy sets flow) and $MF\omega_k$ (angular velocity of fuzzy sets);
b. fuzzy sets output, noted MFH_k (hydraulic load of fuzzy sets);
c. fuzzy rule base (which indicates that between fuzzy sets of input and output fuzzy relationship exists). It contains R_k rules form:

$$if\ Q\ is\ MFQ_k\ and\ \omega_x\ is\ MF\omega_k\ then\ H\ is\ MFH_k.$$

By applying *fuzzyfication*, *inference* (determining *fuzzy rules*) and *defuzzyfication operations* is processed obtain inputs and output fuzzy logic system.

Fuzzyfication operations

This operation transforms input into singleton fuzzy sets. Fuzzy sets input resulting from singleton fuzzyfication defined by membership functions of the form (figure 3).

$$\mu_{MFSQ_k}(Q) = \begin{cases} 1, Q = Q_0 \\ 0, Q \neq Q_0 \end{cases} \quad (3)$$

$$\mu_{MFS\omega_k}(\omega) = \begin{cases} 1, \omega = \omega_0 \\ 0, \omega \neq \omega_0 \end{cases} \quad (4)$$

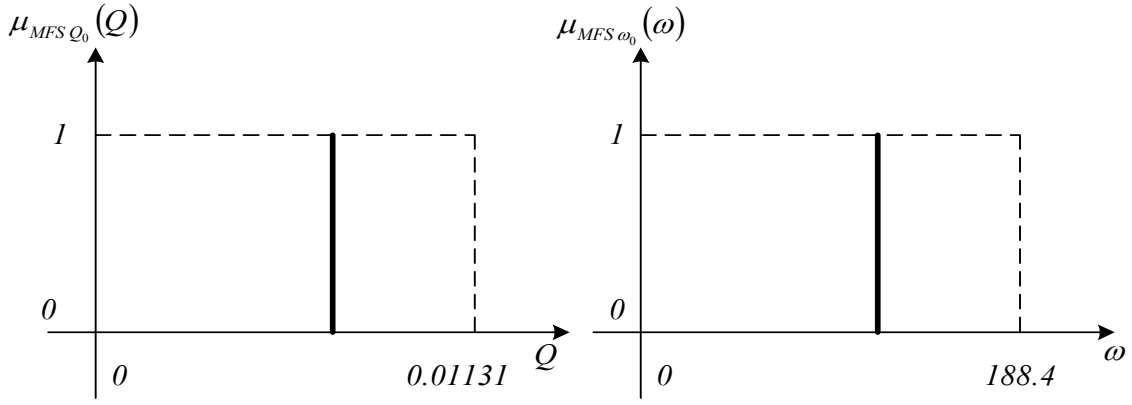

Fig. 3. Fuzzy membership function of input crowds

Range of variation of input variables are intervals of real numbers, for example: $Q = [0, 0.01131]\ m^3/s$ and $\omega = [180, 188.4]\ rad/s$. Is found experimentally that a sufficiently good approximation, while maintaining the complexity of fuzzy logic system to very low limits, coverage is obtained for a *Q-H* characteristic by few fuzzy areas. This implies that the input variables are defined, for exemple, by nine triangular fuzzy sets of type $MFQ1,\ MFQ2, \dots, MFQ9$ (figure 4) for a flow corresponding fuzzy areas 1... 9 and $MF\omega1,\ MF\omega2, \dots, MF\omega9$ the velocity of a fuzzy area 1 to 9. This nine fuzzy sets form a fuzzy partition.

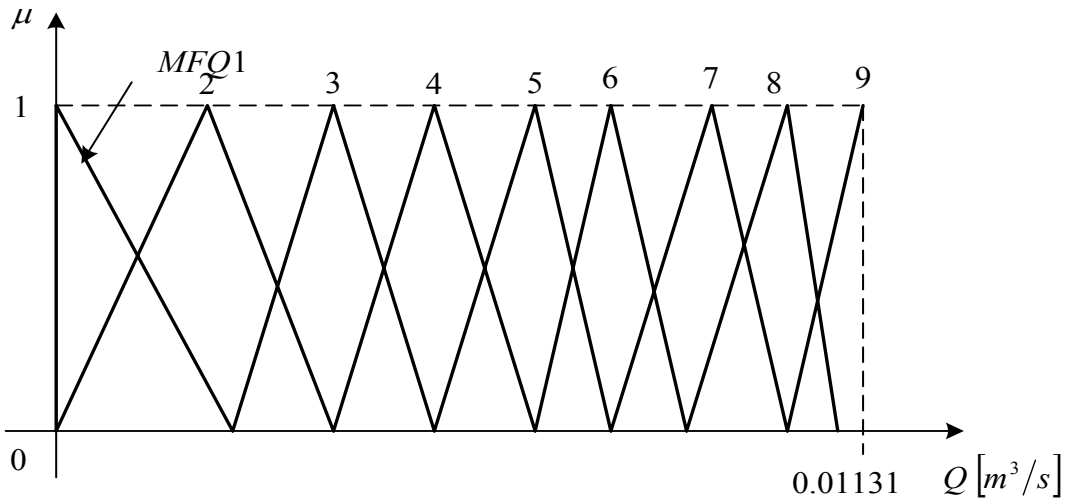

Fig. 4. Fuzzy Sets input variable flow over Q

Defuzzyfication operation

Here is selected a value into fuzzy sets output resulting from inference, noted *MFO*, as the characteristic value of fuzzy crowd-out, for example: $H = [7,\ 34]mcl$.

Hydraulic generator cover feature in the nine areas requires coverage universe fuzzy variable *H* by nine fuzzy sets of triangular shaped $MFH1, MFH2, \ldots, MFH9$ (figure 5).

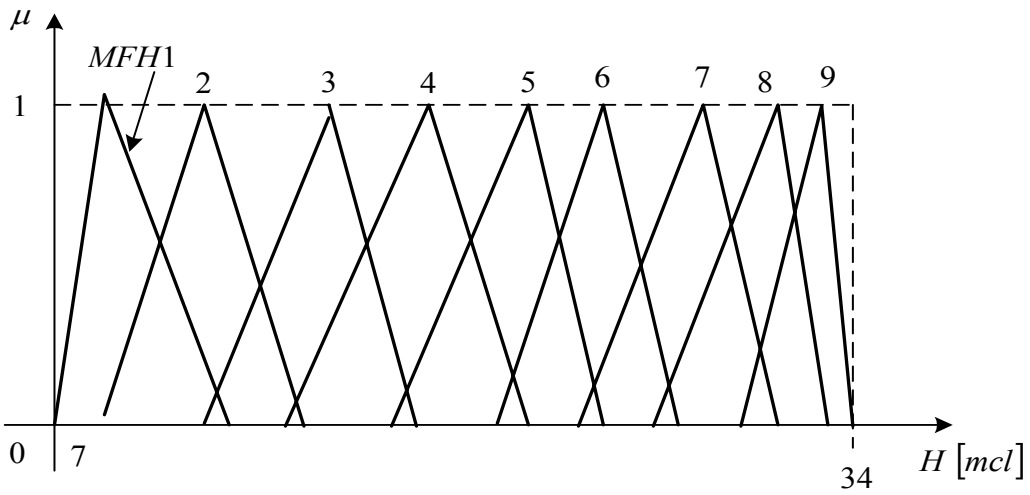

Fig. 5. Fuzzy Sets over variable output hydraulic load H.

Operation selection output value, which is the result fuzzy defuzzyfication $MFH^{'}$ of fuzzy inference, is **central peaks**. This operation means the weighted average of the maximum of each partial conclusions $MFH^{'}_{k}$, where the weights are the maximum values of membership degrees of each $MFH^{'}_{k}$.

Rule base fuzzy logic system

Rule base fuzzy logic system includes all rules that establish relationships between fuzzy sets fuzzy input and fuzzy output. As a result, it looks fuzzy output value MFH_k, $(k = 1, \dots, 9)$ corresponding to each input fuzzy values MFQ_j and $MF\omega_j$ $(j = 1, \dots, 9)$. There will be nine fuzzy rules in rule base system so that each fuzzy rule defines a fuzzy in the nine areas (fig. 6).

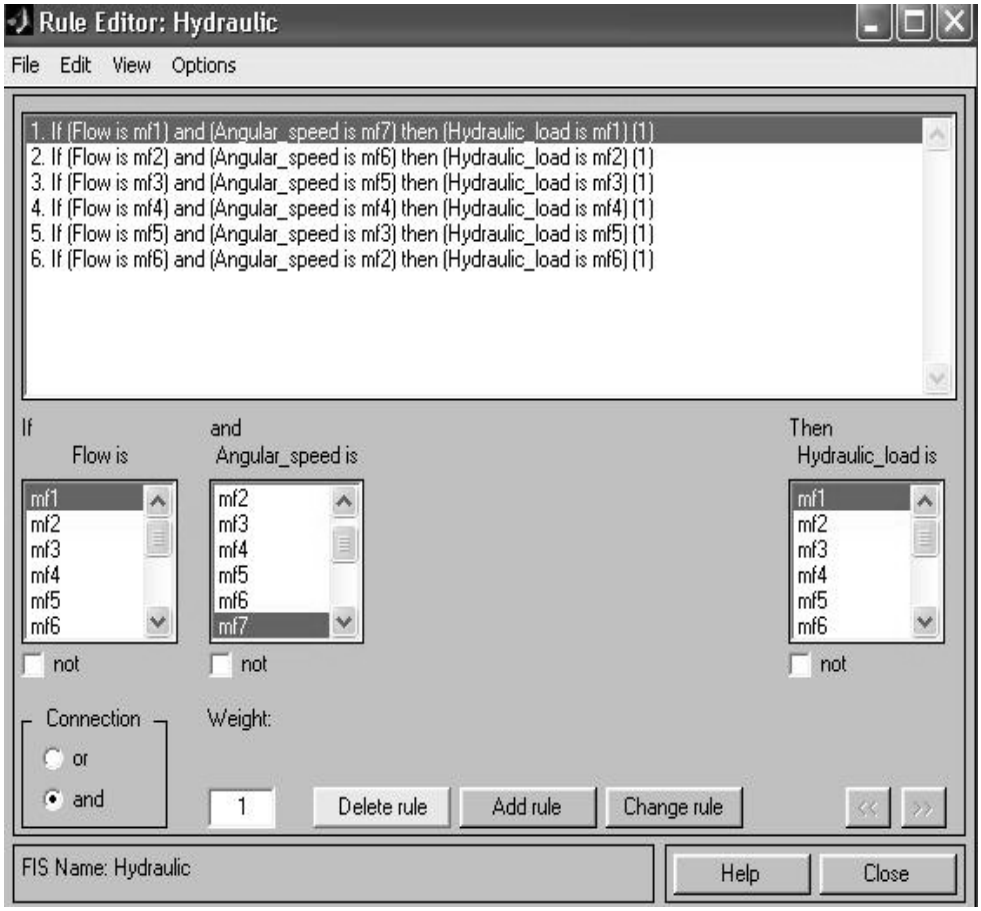

Fig. 6. The first six fuzzy rules

Conclusions

This paper presents the methodology of building a fuzzy logic system in Matlab. For items that are presented which defines a fuzzy logic system: input and output variables of fuzzy logic system, fuzzy sets of input and output, based on fuzzy rules, and operations involved in the operation of the fuzzy logic system : fuzzification, inference (conclusions partial aggregation) defuzzification.

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Sistemul cu logica fuzzy pentru modelarea caracteristicii functionale a generatoarelor hidraulice

Rezumat

Scopul lucrării este de a proiecta un sistem cu logica fuzzy în Matlab folosit pentru modelarea ulterioară a caracteristicii funcționale a generatoarelor hidraulice de tip pompă centrifugă. Lucrarea prezintă metodologia de construire a unui sistem cu logică fuzzy in Matlab. Pentru aceasta sunt prezentate elementele prin care se defineste un sistem cu logică fuzzy: variabile de intrare si de iesire ale sistemului cu logică fuzzy; mulțimi fuzzy de intrare si de iesire; bază de reguli fuzzy, si a operațiilor implicate de funcționarea sistemului cu logică fuzzy: fuzzificare, inferență (agregare a concluziilor partiale), defuzzificare.