DESIGN OF A FUZZY EXPERT SYSTEM FOR MAGNETIC FILTER PERFORMANCE ACCORDING TO MAGNETIC FIELD

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ABSTRACT

Previously theoretical and experimental study was realized for magnetic filter performance according to magnetic field and magnetic susceptibility of the particles. In this study, a fuzzy expert system is designed. In this system, magnetic field strength and particle diameter are selected as input parameters and filter performance is selected as output parameter. All parameters are fuzzified by linguistic expressions. Fuzzy data is evaluated by mamdani fuzzy rule base. And centroid defuzzification method is chosen to get resulted crisp data. FES results and theoretical results are statically analyzed Then, these results and theoretical and experimental data are evaluated. As a result, it is found that mentioned FES can be used in place of theoretical study and experimental work with confidence interval 97. 9%.

I. INTRODUCTION

Magnetic filtration is one of the effective methods for clean out of magnetic particles in technological liquid and gases [1-6] Ferro magnetic materials (sphere, bar, magnetic particles etc.) that are magnetized by external magnetic field are used as filtration elements in magnetic filters. If the magnetized elements are touching to each other then the active regions occur around the tangent points or lines of their peripheries. The principle scheme is shown in Fig. 1 for the case of the magnetized spheres [7].

The performance of this type filters is expressed by the following relation [2-5]:

$$\frac{\psi}{\lambda} = 1 - \exp[-\alpha\chi H^{f}\delta^{2}L/(\eta V_{f}d^{2})] \qquad (1)$$

Technological liquids include the large spectrum of the particles. This formula expresses the dependence of the filter performance on the parameters (magnetic, hydrodynamic geometric) of the filtration system. Some parameters in this formula can not be determined easily, for example dimension of particle (δ) and magnetic susceptibility (χ) [2-5].

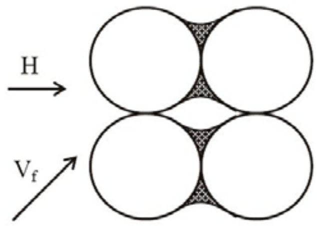

Figure 1. Principle scheme of magnetized ferromagnetic spheres by an external field [7].

Here:
Ψ: Filter performance,
λ : Coefficient indicate ratio the properties of particles,
α : Constant coefficient,
χ : Mean magnetic susceptibility,
$\chi = \chi_p - \chi_f$, χ_p (χ_f) magnetic susceptibility of particles (liquid),
H: Homogeneous external magnetic field,
δ : Dimension of particles (diameter),
L: Length of filter,
V_f : The filtration speed of liquid,
d : The diameter of filter element,
f = 0.5÷1.5 constant coefficient.

Local value of the magnetic field is variable in magnetic filters and this value is one of the important parameters for filter performance. However, susceptibility of the magnetic particles in the liquids used in industry may differ from each other's by 2÷4 times [2]. If the external magnetic field in magnetic filter is about 200 kA/m and more, it becomes apparent how much the magnetic susceptibility of the particles affects the filter performance [7].

Considering the variation of the magnetic susceptibility, the filtration equation becomes:

$$\frac{\psi}{\lambda} = 1 - \exp[-\alpha_1 \chi' H^{1.26} \delta^2 L / (\eta V_f d^2)] \qquad (2)$$

Variation of the magnetic filter performance depend on magnetic field strength was given in Figure 2. The results obtained Eq. 2. and the experimental data [7] are in a good agreement.

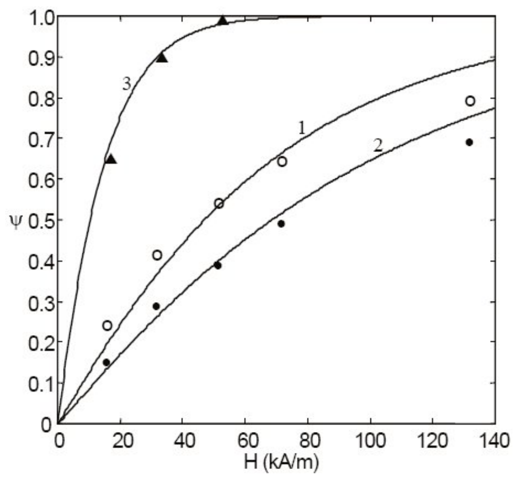

Figure 2. Magnetic filter performance depend on magnetic field strength d=5.7 mm, Vf=0.056 m/s: 1 (o)- δ=0.1-10 μm; 2 (•)- δ<8 μm; 3 (▲)- δ>8 μm [7].

In this study the FES was designed for filter performance according to magnetic field and magnetic depending of particular. Result of FES compared with theoretical and experimental results.

II. FUZZY EXPERT SYSTEMS

Fuzzy logic (FL) is a mathematical discipline that we use every day and helps us to reach the structure in which we interpret our own behaviors. Its basis is formed by "true" and "false" values and Fuzzy Set Theory (FST) in which the values between –"partially true", "partially false"- are determined.

FST is a theory that aims to express the uncertainties of life such as "warm" and "cool" which are in between "hot" and "cold" mathematically. And behind these values there is an unclear numerical value. Generally, fuzzy expert systems (FES) are systems based on knowledge or rule. That is, in the basis of a FES lie the "if-then" rules [8-10].

After deciding on designing a fuzzy system the first step to follow is to collect the rules of "if-then". These rules are generally collected with the help of an expert [11].

As it is seen in Figure 1, in FES model the input and output values of the system are crisp values. By fuzzification these crisp input values, its fuzzy membership values and degrees are obtained. These obtained fuzzy values are processed in fuzzy inference mechanism. Here, the fuzzy output values which are also obtained by using rule-base are sending to the defuzzification unit, and from this unit the final crisp values are obtained as output [12].

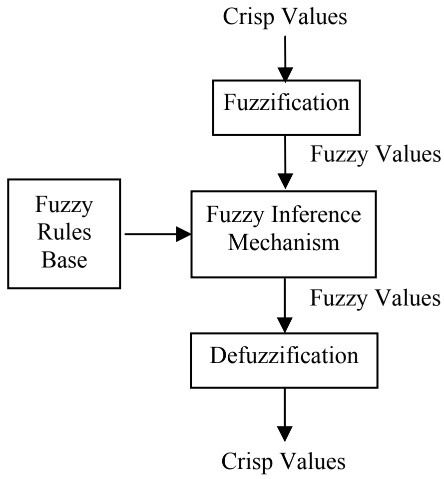

Figure 3. Fuzzy Expert System with fuzzification and defuzzification [11].

III. MATERIAL AND METHOD

Pentium IV 3.0 GHz CPU and 1 Gb RAM, PC and Fuzzy Logic Toolbox software of Matlab version 7 were used in this study. Input parameters, magnetic field (H) and dimension of particles (δ) at designed this system and output parameter, filter performance (ψ) are selected. Then fuzzy sets have been creative for parameters of inputs and output.

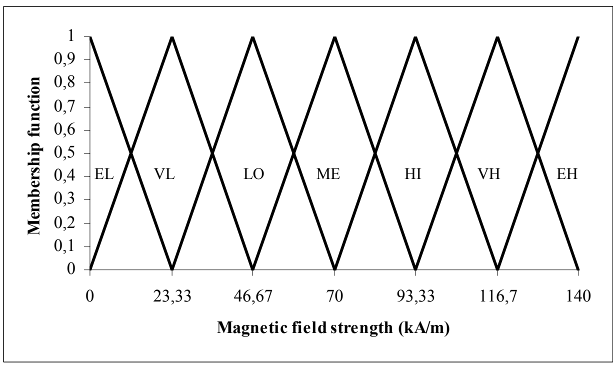

Figure 4. Fuzzy sets for magnetic field strength

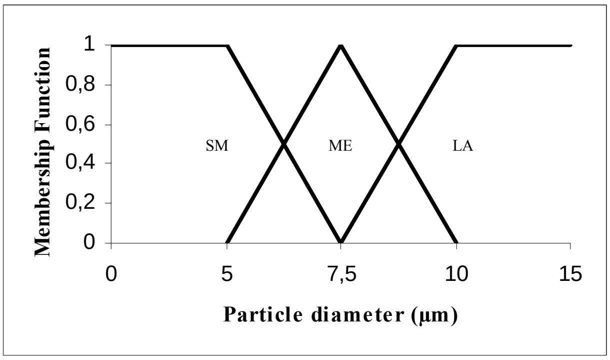

Figure 5. Fuzzy sets for particle diameter.

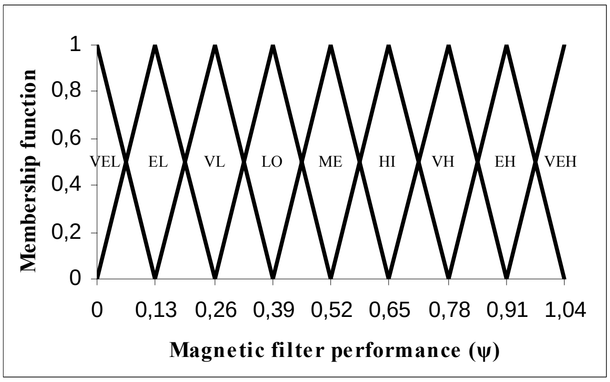

Figure 6. Fuzzy sets for magnetic filter performance.

Table 2. Linguistic expression used in fuzzy sets of magnetic filter performance.

Ψ	Expression
VEL	Very extremely low
EL	Extremely low
VL	Very low
LO	Low
ME	Medium
HI	High
VH	Very high
EH	Extremely high
VEH	Very extremely high

The relationship between inputs and output in a fuzzy system is characterized by set of linguistic statements which are called fuzzy rules [13]. The number of fuzzy rules in a fuzzy system is related to the number of fuzzy sets for each input variable.

In this study 21 (=7x3) fuzzy rules are constructed. An expert is used to construct to rules [13]. As a result build system is given Figure 7. Additionally fuzzy rules are also made up by expert's help.

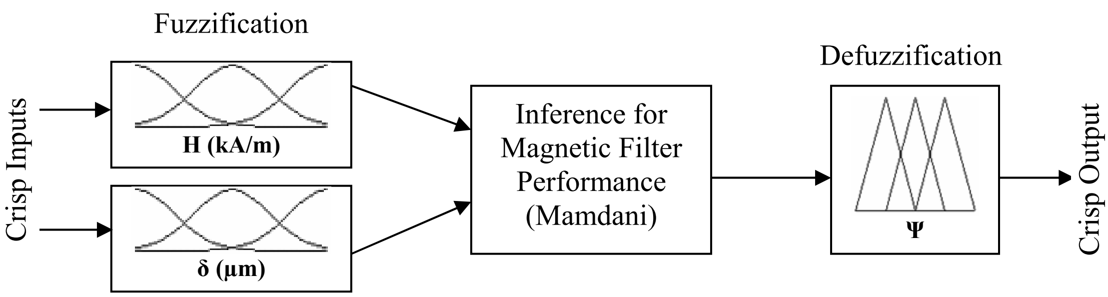

Figure 7. Structure of Fuzzy Expert System

The linguistic expressions for input and output were given consecutive in Table 1 and Table 2.

Table 1. Linguistic expression used in fuzzy sets of magnetic filed strength and particle diameter

H (kA/m)	Expression	δ (µm)	Expression
EL	Extremely low	SM	Small
VL	Very low	ME	Medium
LO	Low	LA	Large
ME	Medium		
HI	High		
VH	Very high		
EH	Extremely high		

Table 3. Fuzzy rule base for magnetic filter performance

Rule		H (kA/m)		δ (µm)		Ψ
1	If	EL	and	SM	Then	EL
2	If	EL	and	ME	Then	VL
3	If	EL	and	LA	Then	HI
…	…	…	…	…	…	…
19	If	EH	and	SM	Then	HI
20	If	EH	and	ME	Then	VH
21	If	EH	and	LA	Then	VEH

Designed system is run and results are extracted. Then resulting data is compared with both theoretical and experimental data.

Table 4. Obtained filter performance values by FES δ1 0.1-7.5 (μm) δ2 5-10 (μm) δ3 7.5- 15 (μm)

H (kA/m)	δ1 (μm)	δ2 (μm)	δ3 (μm)
18,00	0,23	0,35	0,83
30,00	0,30	0,43	0,92
50,00	0,41	0,54	1,00
70,00	0,52	0,65	1,00
90,00	0,63	0,76	1,00
110,00	0,65	0,78	1,00
130,00	0,65	0,78	0,99

IV. RESULTS AND DISCUSSION

Magnetic field strength and magnetic susceptibility of particles that are captured in the magnetic filters used for industrial cleaning liquids affect the performance.

In this study magnitude of magnetic field strength requirements for other particles having different diameters can be predicted.

As shown in the Figure 8, results obtained by designed FES.

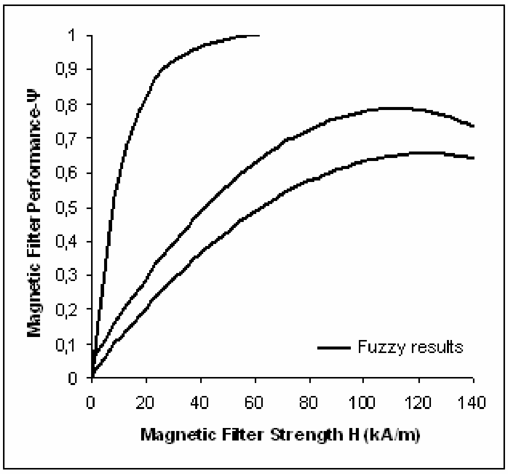

Figure 8. Modeling of magnetic filter performance dependences to magnetic field strength. (♦) 0.1-7.5 μm; (■) 5-10 μm; (▲) 7.5- 15 μm

It was compared of FES and experimental results in Figure 9. And it was compared of FES and theoretical results in Figure 10. FES, theoretical and experimental results are similar.

The result obtained by statistical correlation analysis with Matlab version 7 is correlated each other with 97.9%.

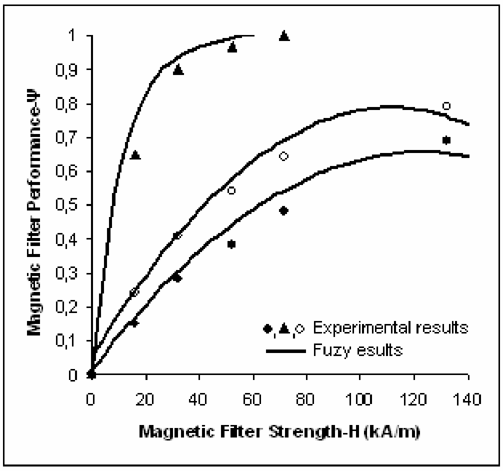

Figure 9. Comparing of obtained FES and experimental data

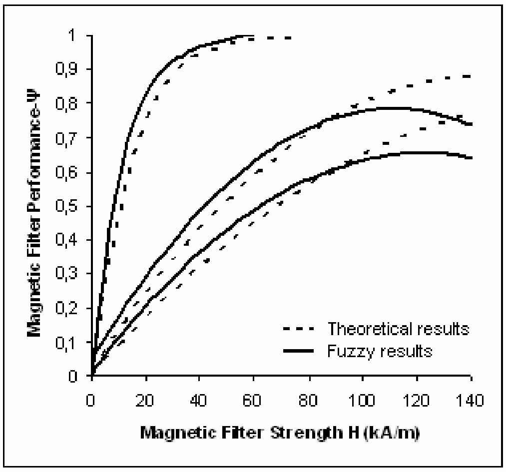

Figure 10. Comparing of obtained FES and theoretical data

V. CONCLUSION

This study shows that magnetic susceptibility of captured particles in the magnetic filter affects significantly catching properties and consequently also affects filter performance.

It can be seen easily that theoretical and experimental data and obtained FES data are close to each other. Consequently designed FES can be used reliably in place of theoretical study and experimental work.

Better results can be obtained by increasing the number of the rules and linguistic expression of parameters. Also this system can be enhanced by hybridizing with other artificial intelligent methods and improved results can also be obtained.

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