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Fuzzy Neural Network Based Analysis of the Process of Oil Product Sorption with Foam Polystyrene

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ABSTRACT
A set of series of neural network models was applied to the field of chemistry. In this paper a fuzzy neural network is used for analysis of the process of oil product sorption with foam polystyrene. Knowledgebase is extracted from data by using sub clustering method. Knowledgebase is realized in environment Matlab. Obtained results have demonstrated efficiency of the proposed method and its advantages as compared to the existing empirical knowledge . Experimental investigations show the validity and applicability of the suggested model and reasoning system.
Keywords: Process of oil product sorption, membership function, Fuzzy Neural Network, compressor oil, kerosene, transformer oil, industrial oil

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I. INTRODUCTION

The need in chemical methods based on information which is characterized by ambiguity at the stages of the development of natural sciences and the connection between chemistry and other sciences have brought to the forefront the importance of such a topical problem as fuzzy chemistry development.

Development of new information technology exerts an influence on most areas of science including chemistry [1-2]. Recently, methods based on application of computer sciences including the Soft Computing technology are used in chemical process simulation.

It is demonstrated by articles published in scientific literature [3-11]. These papers present the application of soft computing technology in the sorption process. However none of them takes into consideration the effectiveness of information description means and the way of such description. As known, wrong information leads to making a wrong decision. Since information expresses human subjective thoughts, there are ambiguities in its description. Urgency of the problem of ambiguous information processing was proved by many scientific papers.

The summary of papers related to the application of the fuzzy logic theory and neural networks to the process of sorption shows that the missing aspects of these two paradigms, teaching and interpretation, have negative effect on obtained results and are the cause of increased error in the results obtained in modelling. In such a case, the hybrid fuzzy neural network is used as an effective means but it is not a perfect means. It also involves the factors influencing on the result – the problem of right choice of a membership function type and a clustering algorithm. This article analyzes features of application of the fuzzy neural network in the process of oil product sorption taking into consideration the above mentioned problem.

Let's consider some specific features of the process of oil product sorption from water surface using foam polystyrene (FP). The process of sorption was multistage and heterogeneous and consisted of the following stages: adding a sorbing agent to the surface of an environmental sample, effect of sorbate on the sorbent holes, adsorption of the sorbate to the polymer surface. In specific situations, in addition to the above mentioned processes adsorption may take place in the result of dissolution of the polymer surface layer. Diffusion of oil and oil product in the volume of polymer results in change of macromolecule configuration and swelling. The sorbents in question have a cross-linked structure, however swelling of sorbents in oil and oil products is slightly observed.

Let's consider some of major points which characterize sorption capacity if the sorbent before we determine the relationship between the process of oil and oil product sorption and the sorbent's macrostructure. In the case under discussion, the foam polymer sorbent has the closed hole structures isolated from each other. Holes in sorbent were isolated and filled with nitrogen. And this in turn serves as a float which provides floatability.

II. STATEMENT OF THE PROBLEM

Study of real life processes is based on practical knowledge. However sometimes running of experiments requires extra costs. From this point of view, study of processes based on modelling is considered more expedient. Experimental findings are used for modelling. These findings are the results of various tests. Testing depends on a number of factors. For example, the testing period, raw material volume, composition, etc. There are the processes whose modelling mandatorily requires running of experiments in laboratory setting. For example, material model building is carried out in laboratory setting and complicated calculations require mandatory computer simulation.

Several repetitions of one and the same experiment in chemical processes is characterized by loss of time and raw material. However modelling makes it possible to avoid this problem. The model's parameters have a direct effect on modelling results. For example, results obtained from the sorption process depend on density and test period interval.

The purpose of this paper is to analyze the process of oil product sorption with foam polystyrene based on the fuzzy neural network. The purpose of choice of the fuzzy neural network based method is to obtain test results using the knowledge gained during an experiment.

Here, the author took experimental results as primary data [12-14]. 1/3 of these data were used for test and 2/3 were used for creating a model. Data used for test and a fragment of primary data are given in Table 1-2 below.

III. SOLUTION METHOD

Chemical process forecasting and classification problems under statistical uncertainty are successfully solved based on traditional methods of mathematics and statistics.

Table 1. Primary data fragment

Density, kg/m3	Test period, h	Sorption capacity, kg/kg			
		Compressor oil	Transformer oil	Industrial oil	Kerosene
80	3	8.0	7.6	8.2	7.8
	10	8.7	8.5	8.7	7.9
	24	8.9	9.0	9.1	8.0
	48	9.0	9.4	9.5	8.0
190	3	9.9	9.8	9.6	8.2
	10	10.6	10.3	10.5	8.6
	24	11.6	10.9	11.4	9.4
	48	12.1	11.6	12.6	9.5
310	3	11.6	12.2	11.2	8.7
	10	12.5	13.0	12.6	9.5
	24	13.0	13.8	13.5	9.7
	48	13.9	14.1	14.2	9.7
520	3	5.5	5.1	6.0	9.0
	10	6.7	6.0	6.3	9.9
	24	7.5	6.4	6.7	12.8
	48	7.6	6.6	7.0	13.1

These methods make it possible to build models with large enough data volume for instantiation of statistical hypotheses. However under non-statistical uncertainty, when analyzed data are fuzzy and it is impossible to determine the volume of data or they are incomplete and contradict each other, such models are considered to be ineffective. In such a case, the forecasting model and methods based on expert knowledge are considered to be more adequate. Such forecasting model and methods are based on the Soft Computing technology which covers fuzzy logic and neural computing paradigms.

Let's consider the architecture and layers of the used neural fuzzy system. Logical induction in the neural fuzzy system is carried out in the form of 5-layer network. In the process, the 1st layer performs input variable terms, the 2nd layer performs fuzzy rule antecedents (conventional parts), the 3th layer performs standardization of rules execution, the 4th layer performs completeness of rules and the 5th layer performs consolidation of the results obtained on various rules.

Let us assume that x,y are the system inputs and z is an output. Then, the rule written with fuzzy data is as follows:

P1: if x is A_1 and y is B_1, then z is C_1,

P2: if x A_2 and y is B_2, then z C_2,

Here, let's describe the membership function of x and y values $\mu_r(x_i) = e^{\frac{-(x-c)^2}{2\sigma^2}}$ using the two-sided Gauss membership function. Here, sigma is the concentration factor, c is the maximum point of the membership function value. The solution path consists of the following stages [15]:

1) One term of each point of the 1st stage layer is described by the membership function.

2) at the 2nd stage $\alpha_1 = A_1(x_0) \wedge B_1(y_0), \alpha_2 = A_2(x_0) \wedge B_2(y_0),$ i.e. the truth degree of the rule execution is found and individual outputs of the rile is presented as follows:

$$z_1^* = a_1 x_0 + b_1 y_0,$$

$$z_2^* = a_2 x_0 + b_2 y_0.$$

3) fuzzy output values are defined at the last stage.

$$z_0 = \frac{\alpha_1 z_1^* + \alpha_2 z_2^*}{\alpha_1 + \alpha_2}$$

IV. COMPUTER SIMULATION

The used primary data fragment is given in Table 1. Two input and one output neural network models were built for testing. The structure of the built neural network is given in Fig.1. The number of rules obtained by the subtractive cluster method is 9.

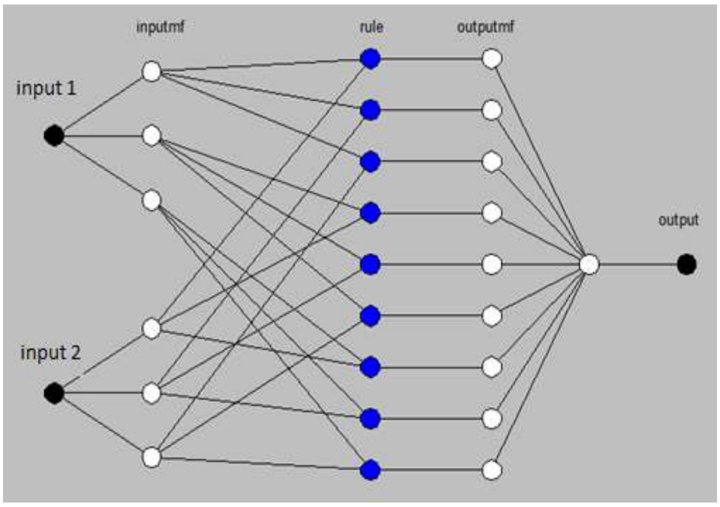

Fig 1. Structure of the fuzzy neural network

A fragment of primary data used in training and test during modelling is given in Tables 2-7.The system error for the results obtained from the model (Fig.2.) built for compressor oil is 2.1009e-005; the test error for data presented in the figure [310 10] is 1.785714; the total test error is 5.033263(Table 4). Each test error was calculated by the following formula: $RMSE = \sqrt{\frac{\sum_{i=1}^{N}(M_{i\exp} - M_{ipre})^2}{N}}$ Here N=7, $M_{i\exp}$ -experimental value, M_{ipre} -test result.

Table 2. Data fragment used in training

Density,kg/m^3	Test period, h	Sorption capacity, kg/kg			
		Compressor oil	Transformer oil	Industrial oil	Kerosene
80	3	8.0	7.6	8.2	7.8
	24	8.9	9.0	9.1	8.0
190	10	10.6	10.3	10.5	8.6
	48	12.1	11.6	12.6	9.5
310	3	11.6	12.2	11.2	8.7
	24	13.0	13.8	13.5	9.7
	48	13.9	14.1	14.2	9.7
520	10	6.7	6.0	6.3	9.9
	24	7.5	6.4	6.7	12.8
	48	7.6	6.6	7.0	13.1

Table 3. Data fragment used in the test

Density,kg/m^3	Test period, h	Sorption capacity, kg/kg			
		Compressor oil	Transformer oil	Industrial oil	Kerosene
80	10	8.7	8.5	8.7	7.9
	48	9.0	9.4	9.5	8.0
190	3	9.9	9.8	9.6	8.2
	24	11.6	10.9	11.4	9.4
310	10	12.5	13.0	12.6	9.5
520	3	5.5	5.1	6.0	9.0

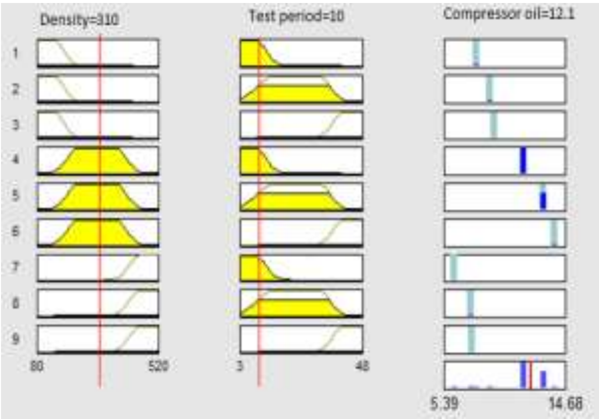

Fig. 2. Results of computer simulation conducted for compressor oil

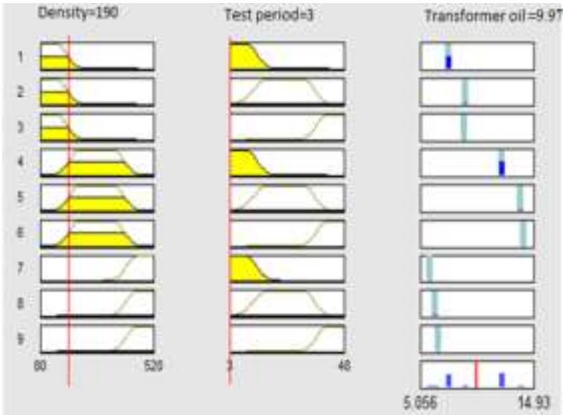

Fig. 3. Results of computer simulation conducted for transformer oil

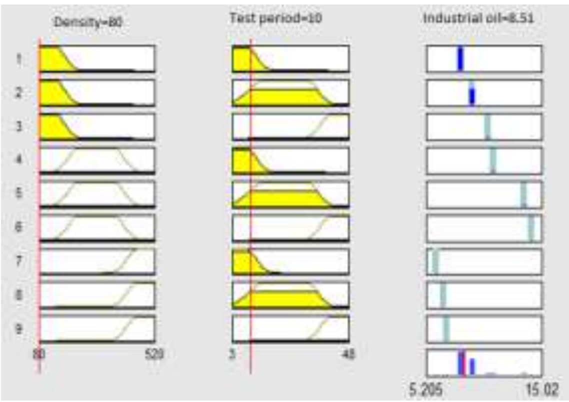

Figure 4. Results of computer simulation conducted for industrial oil

Table 4. Test results for compressor oil

Experi mental value	Test result	Devia tion	Error
8,7	8,30	0,4	4,597701
9	9,29	0,29	3,222222
9,9	10,2	0,3	3,030303
11,2	*11,4*	*0,2*	*1,785714*
12,5	12,1	0,4	3,2
5,5	6,29	0,79	14,36364
			5,033263

Table 5.
Test results for transformer oil

Experi mental value	Test result	Deviat ion	Error
8,5	7,91	0,59	6,941176
9,4	8,95	0,45	4,787234
9,8	*9,97*	*0,17*	*1,734694*
10,9	11,5	0,6	5,504587
13	12,6	0,4	3,076923
5,1	5,89	0,79	15,4902
			6,255802

Table 6. Test results for industrial oil

Experi mental value	Test result	Deviation	Error
8,7	*8,51*	*0,19*	*2,183908*
9,5	10,5	1	10,52632
9,6	9,91	0,31	3,229167
11,4	11,6	0,2	1,754386
12,6	12	0,6	4,761905
6	6,09	0,09	1,5
			3,992614

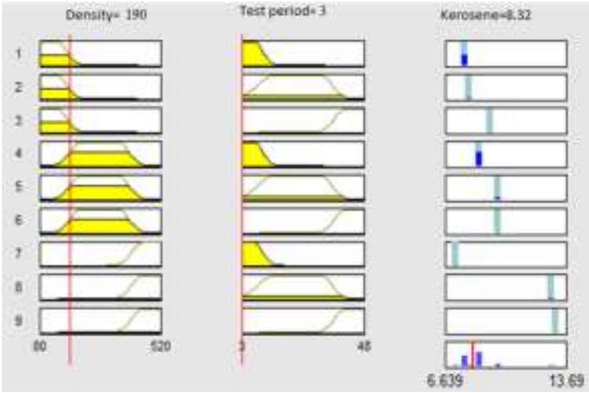

Figure 5. Results of computer simulation conducted for kerosene

Table 7. Test results for kerosene

Experi mental value	Test result	Deviat ion	Error
7,9	7,88	0,02	0,253165
8	9,23	1,23	15,375
8,2	*8,32*	*0,12*	*1,463415*
9,4	8,93	0,47	5
9,5	9,12	0,38	4
9	7,78	1,22	13,55556
			6,607856

The results of computer simulation conducted for transformer oil is given in Table 5. The system error is 0.00018324; test error for data presented in Fig. 3 - [190 3] is 1.734694; the total test error is 6.255802.

The values given in Table 6 are the results of conducted tests. Each test error and the total test error are presented in the table. In this case, the system error is 7.7293e-005; test error for data presented in Fig.4.- [80 10] is 2.183908; the total test error is 3.992614.

The following methods were used in modelling: Type of inference ='sugeno', Number of inputs=2, Number of oputput=1, Number of rules=9, AND operation ='min',OR operation ='Algebraic sum', Implication method ='product', Aggregation method ='max',Defuzzification method ='centroid'

In Table 7, the system error on kerosene is 5.4327e-005; test error on data given in Figure 5 for [190 3] is 1.463415; the total test error is 6.607856.

V. CONCLUSION

The article analyzes the process of sorption of oil products with foam polystyrene based on the fuzzy neural network. The results obtained for the model were compared to real test results. The total error for each product didn't exceed 7% and the error of each test was even lower. And this result was accepted in statistical calculations. We conducted tests in the built model with the permissible error of experimental results using the methods of soft computing technology. The used method is based on obtaining the rules of production type by the method of cluster from experimental data and test results are determined using the model of logical induction based on these rules. The model presented in the article can be used in the analysis of chemical processes.

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