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DEVELOPMENT OF LINGUISTIC MODELS FOR EVALUATING QUALITY INDICATORS OF BENZENE AT THE OUTLET OF THE BENZENE COLUMN IN A FUZZY ENVIRONMENT

Annotation: *Currently, due to the intensive development of the petrochemical industry and the growing demand for its products, increasing the productivity of high-quality benzene production facilities based on their models has become an actual scientific and practical problem. In practice, the main indicators of benzene quality are assessed imprecisely based on the experience and knowledge of process engineers who manage the benzene production process and specialists from the plant laboratory. The paper proposes a method for synthesizing linguistic models of poorly formalized technological facilities, such as a benzene column, with fuzzy input and output parameters, allowing for the modeling and optimization of their operating modes in a fuzzy environment. Based on the proposed method, linguistic models have been developed to evaluate the main quality indicator of benzene produced in the benzene column of the Atyrau oil refinery, which is the subject of the study. Based on the developed linguistic models-a rule base in Fuzzy Logic Toolbox-fuzzy modeling of various operating modes of the studied benzene column and optimization of its mode were carried out. As a result, the optimal operating mode of the benzene column was determined, allowing to maximize the volume and quality of benzene from its output. The novelty and importance of the proposed method for synthesizing linguistic models of complex technological objects in a fuzzy environment lies in the fact that it allows the development of effective linguistic models of objects with fuzzy input and output parameters. The practical significance of the developed linguistic models of the object under study lies in the optimization of its operating modes in a fuzzy environment based on fuzzy modeling.*

Key words: *benzene column, fuzzy modeling, optimization, linguistic models, benzene production process.*

Introduction

The benzene column, designed to produce benzene from naphtha with quality indicators that meet current standards, is the main unit of the benzene production unit (BPU) at oil refineries (OR). The quality indicators of benzene, such as the average octane number of benzene and the sulfur content in benzene from the benzene column at the Atyrau and many other refineries, are not directly measured in production. These important indicators, which determine the quality of benzene in practice, are assessed imprecisely with the participation of process operators, decision-makers (DMs) responsible for managing the benzene production process, and specialists from the plant laboratory [1, 2]. At the same time, they determine these qualitative indicators of benzene based on their knowledge, experience, and intuition, as well as additional research in laboratory conditions using fuzzy expressions: “less,” “more,” “low,” “medium,” “high” quality, etc. [3]. Accordingly, to determine such vaguely assessed parameters and indicators of poorly formalized production facilities, it is necessary to use available fuzzy information obtained from decision makers and expert specialists based on expert assessment methods and processed using fuzzy set theory methods [4, 5].

Recently, with the intensive development of the petrochemical industry, in which high-quality benzene obtained at oil refineries is the main raw material, issues related to the optimization and management of the benzene production process in oil refinery benzene columns have become a highly relevant and priority task for the oil refining and petrochemical industries. In this regard, research dedicated to solving this problem using mathematical models and information technology has intensified. Several studies [6-11] are devoted to the problems of developing mathematical models and simulating benzene production facilities. The authors of [6, 7] presented the results of research into the processes of benzene production by hydrodealkylation and from naphtha in oil refineries and the problems of optimizing these processes based on mathematical modeling under deterministic conditions. Zhilin, Franck, and others in their works [8, 9] investigated issues of modeling the technology of benzene and toluene production based on the synthesis and production of high-quality benzene for use in petrochemistry under conditions of stochastic uncertainty. Han et al. in their work [10] investigated the conversion of benzene and synthesis gas into alkylbenzenes using various catalysts based on kinetic models describing the rates of chemical reactions and their mechanisms, as well as the influence of temperature.

The sources analyzed above and other sources on the subject mainly examine the problems of modeling benzene production processes under deterministic conditions and under conditions of stochastic uncertainty, while the problems of modeling in optimization under conditions of uncertainty have not been sufficiently studied. Works [11, 12] examine the problems of developing fuzzy models and multi-criteria optimization of hydrocarbon production facilities, including benzene, with clear input and fuzzy output parameters. However, in these and other known similar works, the problems of developing linguistic models under conditions of fuzzy input and output parameters of benzene production facilities have not yet been sufficiently studied and solved. In this regard, the development of an effective method for synthesizing linguistic models for linguistic modeling of facilities with fuzzy input and output parameters is a relevant scientific and practical task for many poorly formalized facilities, such as benzene columns, operating in a fuzzy environment. This work is devoted to the study and solution of this task, i.e., the development of linguistic models for evaluating the quality indicators of benzene at the outlet of the benzene column of the BPU in a fuzzy environment.

Research methods

The conditions for conducting the study are the availability and use of the following materials and information:

– technological regulations for the operation of the benzene column of the BPU and a description of its technological scheme [1];

– results of various studies and analyses, assessments of the quality characteristics of benzene and benzene quality requirements according to current standards [3, 10];

– standards and methods for determining benzene quality indicators, such as: GOST 9572-93; ASTM D2699; ISO 22854; GOST 511-82; spectroscopic methods [13, 14];

– unclear information obtained from the decision-maker responsible for managing the benzene production process and expert specialists from the plant laboratory.

The benzene column C-401 BPU of the Atyrau Oil Refinery, in which benzene production processes take place, was selected as the object of study. The main quality indicators are taken into account as fuzzy constraints according to the requirements of current standards. The main fuzzy quality indicators controlled in the benzene production process in accordance with the requirements of current standards are: $\mu_1(\mathbf{x})=$ «the average octane number of benzenes is greater than: $\tilde{\geqq}102$» and $\mu_2(\mathbf{x})=$ «the sulfur content in the produced benzene is less than: $\tilde{\leqq}0.00005$». Here, $\mu_1(\mathbf{x})$ and $\mu_2(\mathbf{x})$ are membership functions that formalize the fuzzy descriptions of the constraints, determining the dependence of the fuzzy constraints on the vector of input operating parameters of the benzene column $\mathbf{x}$. These fuzzy constraints are described by term sets: {“low”, “below average”, ‘average’, “above average”, “high”}, for each term, for which membership functions $\mu_q(\mathbf{x})$, $q=1,2$, are constructed, which evaluate the degree of fulfillment of fuzzy constraints:

In this work, the collection and processing of statistical and experimental data are implemented using methods of mathematical statistics and probability theory [15, 16]. To obtain fuzzy information from decision makers and experts, and to process and use it, expert assessment methods and fuzzy set theory are used [17, 18]. The paper also proposes and uses a new method for synthesizing linguistic models for complex production facilities such as a benzene column operating in a fuzzy environment. The MATLAB system toolkit Fuzzy Logic Toolbox [19] is used for fuzzy modeling of the benzene column operation and visualization of the results.

The proposed method for synthesizing linguistic models is based on conditional logical inference rules, a production model of knowledge representation, and various operations on fuzzy sets. Below are the main stages of the method for synthesizing linguistic models of complex technological systems with fuzzy input and output parameters.

1. Selection of fuzzy input and operating parameters of the modeled object $\tilde{x}_i$, $i = \overline{1,n}$ that affect the values of its fuzzy output parameters $\tilde{y}_j, j = \overline{1,m}$, which are optimized.

2. Definition of the term set $T(X,Y)$ for fuzzy description of selected fuzzy inputs, mode $\tilde{x}_i$, $i = \overline{1,n}$ and outputs $\tilde{y}_j, j = \overline{1,m}$, value parameters, i.e., a set of terms that are represented as linguistic variables. Also, definition of universes X and Y, i.e., intervals of variation of fuzzy input and output parameters.

3. Construction of membership functions that formally describe the degrees of membership of terms in fuzzy sets that vaguely describe the values of linguistic variables $\tilde{x}_i$, $i = \overline{1,n}$ and $\tilde{y}_j, j = \overline{1,m}$ i.e., implementation of fuzzification procedures.

4. Building a rule base based on a production model of knowledge representation and logical rules of conditional inference, and synthesizing linguistic models with the following structure:

$$IF\ \ \tilde{x}_1 \in \tilde{A}_1\ and/or\ \tilde{x}_2 \in \tilde{A}_2, \dots, and/or\ \ \tilde{x}_n \in \tilde{A}_n\ THEN\ \ \tilde{y}_j \in \tilde{B}_j, j = \overline{1,m}. \tag{1}$$

To synthesize linguistic models that vaguely describe the influence of fuzzy input parameters $\tilde{x}_i$, $i = \overline{1,n}$ on fuzzy output parameters $\tilde{y}_j, j = \overline{1,m}$ of a fuzzy object, expert assessment methods and fuzzy set theories are used.

5. Construction of fuzzy mappings $\tilde{R}_{ij}$, describing fuzzy relationships between linguistic variables $\tilde{x}_i, i = \overline{1,n}$ и $\tilde{y}_j, j = \overline{1,m}$, of the optimized object. For convenience, fuzzy mappings $\tilde{R}_{ij}$ are formalized through their membership functions $\mu_{\tilde{R}_{ij}}(\tilde{x}_i, \tilde{y}_j)$. Then, based on the compositional inference rule $\tilde{B}_j = \tilde{A}_i \circ \tilde{R}_{ij}$, where $\tilde{A}_i \subset X,\ \tilde{B}_j \subset Y$,and X, Y are universal sets defined in step 4. For each term *t* from the term sets $T(X,Y)$, the fuzzy mapping can be defined by the Cartesian product of the corresponding universal sets: $\tilde{R}_{ij}^t = \tilde{A}_i^t \times \tilde{B}_j^t$.

6. For convenience, the fuzzy relation matrices $\mu_{\tilde{R}_{ij}}^t(\tilde{x}_i, \tilde{y}_j)$ are calculated based on the membership function of the fuzzy mapping $\tilde{R}_{ij}^t$ using the formula:

$$\mu_{\tilde{R}_{ij}}^t(\tilde{x}_i, \tilde{y}_j) = min\left[\mu_{\tilde{A}_i}^t(x_i), \mu_{\tilde{B}_j}^t(y_j)\right], i = \overline{1,n}, j = \overline{1,m}, \tag{2}$$

based on which the values of the membership functions of the output parameters $\tilde{y}_j, j = \overline{1,m}$: are determined:

$$\mu_{\tilde{B}_j}^t(y_j') = \max_{x_i \in X}\{\min[\mu_{\tilde{A}_i}(x_i^*), \mu_{R_{ij}}(\tilde{x}_i, y_j^M)]\}. \tag{3}$$

Here, x_i^* are fuzzy values of input and operating parameters estimated by experts. Then, the desired set, to which the current values of input and operating parameters belong, is determined by the formula $\mu_{A_i}(x_i^*) = \max_i \mu_{A_i}(x_i)$, i.e., as a set in which the values of the operating parameters have the maximum values of the membership function.

7. The adequacy condition of the obtained model is checked $\min \sum_{j=1}^{m}(y_j^M - y_j^E)^2 \leq S_R$, , where y_j^M are the defased values of the output parameters of the technological system; y_j^E are the actual values of the output parameters obtained experimentally on the technological system under study; S_R is the specified level of adequacy. The values y_j^M and y_j^E must be obtained at the same values of $x_i^*, i = \overline{1,n}.$

If the condition is not met, then starting from stage 5, the next iteration of synthesizing more adequate models is performed.

8. Synthesized linguistic models with the necessary adequacy are output, and fuzzy modeling is performed to optimize the output parameters of the object under study.

When the condition of step 7 is met, the transition to the next step 8 is made.

A block diagram of the algorithm implementing the proposed method of linguistic model synthesis is shown in Figure 1.

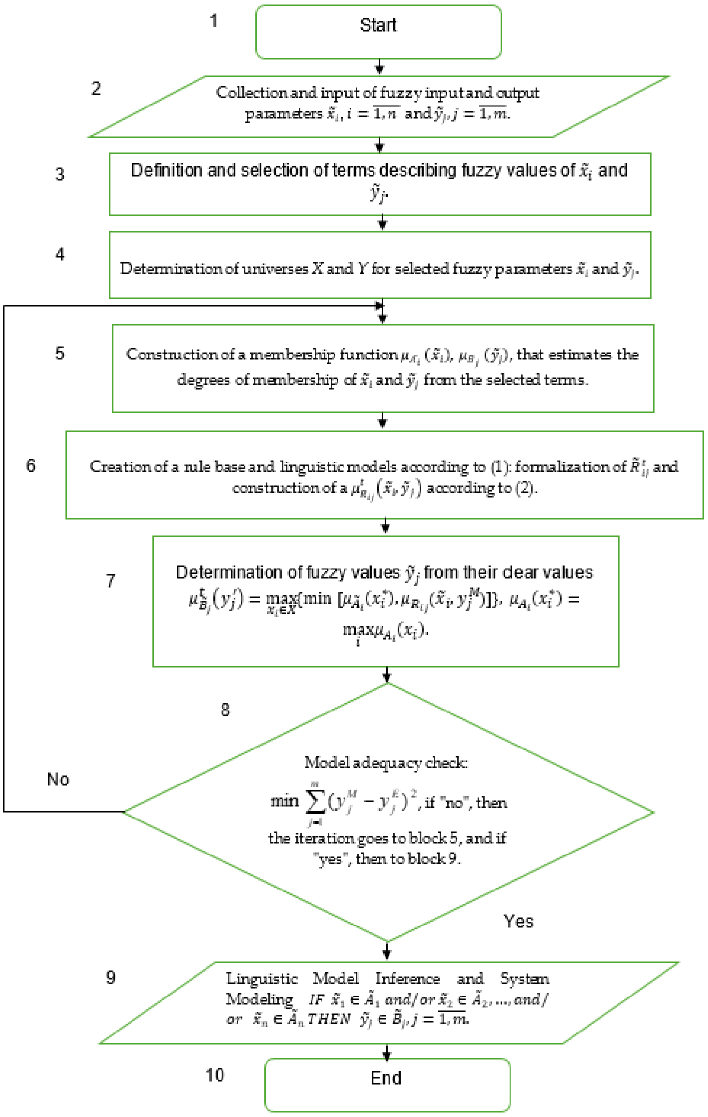


Figure 1 – Block diagram of the algorithm for implementing the proposed method for synthesizing linguistic models of complex objects with fuzzy input and output parameters

Research results

Using the proposed method of linguistic model synthesis, linguistic models were synthesized that allow the average octane number of benzenes to be estimated, which is the main quality indicator of benzene produced from a benzene column. Then, fuzzy modeling was performed in the MATLAB Fuzzy Logic Toolbox.

In accordance with block 2 of the algorithm for implementing the method of synthesizing linguistic models based on the Delphi method, the following input parameters were selected as the operating parameters that most influence $\tilde{y}_1$ the average octane number of benzenes from the benzene column outlet: $\tilde{x}_1$, $\tilde{x}_2$ – operating parameters: temperature and pressure values in the benzene column, characterized by fuzzyness and being linguistic variables.

As a result of implementing block 3, the following term sets were defined, which describe $\tilde{x}_1$, $\tilde{x}_2$ and $\tilde{y}_1$ in a fuzzy manner:

$\tilde{x}_1$ = {«low», «below average», «average», «above average», «high»};

$\tilde{x}_2$= {«low», «below normal», «normal», «above normal», «high»};

$\tilde{y}_1$= {«very low», «low», «average», «high», «very high»}.

For formalization and further convenience, the terms describing the fuzzy values of the parameters are denoted by the symbols given in Table 1.

Table 1 – Terms describing fuzzy parameter values and their designations used in constructing their membership functions and creating a rule base

Therms describing fuzzy parameter values	**Designation**
Low, low	*LW* (Low)
Below average, below normal	*BA,* (Below average), *BN* (below normal)
Average, average, normal	*AR* (Average), *NR* (normal)
Above average, above normal	*AA* (Above average), *AN* (above normal)
High, high	*HG* (High)
Normal	*NR* (Normal)
Very low	*V LW* (Very low)
Very high	*VHG* (Very high)

Block 5 defines the universes for linguistic variables $\tilde{x}_1$, $\tilde{x}_2$ and $\tilde{y}_1$ used in constructing the membership function in block 5. The results are shown in Table 2 below.

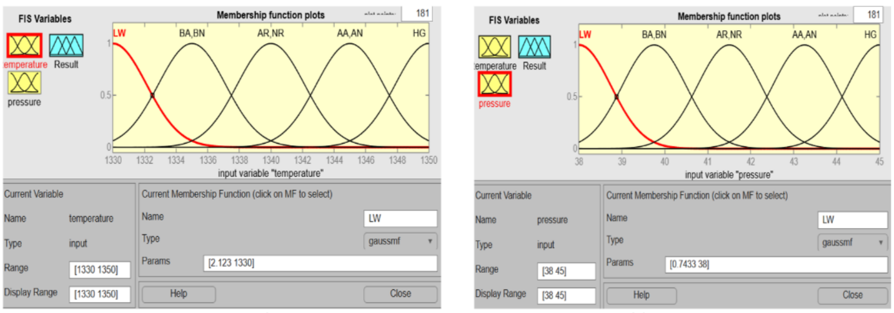
Table 2 – Universes for linguistic variables $\tilde{x}_1$, $\tilde{x}_2$ and output parameter $\tilde{y}_1$

Linguistic variables	**Designations of terms, meanings of linguistic variables**				
	LW	*BA, BN*	*AR, NR*	*AA, AN*	*HG*
$\tilde{x}_1$ – column temperature C-401, °C	1324-1336	1328-1342	1334-1346	1340-1352	1344-1356
$\tilde{x}_2$ – column pressure C-401 kg/cm^2	35-40	37-42	39-44	41-46	43-48
Fuzzy output parameter	**Designations of themes and meanings of fuzzy output parameters**				
	V LW	*LW*	*AR*	*HG*	*VHG*
$\tilde{y}_1$ – average octane number of benzene	97-103	100-104	103.4-103.6	103.8-104.2	104-106

Let's present the results of the fuzzy faction procedure and other fuzzy inference procedures using the Fuzzy Logic Toolbox application of the MATLAB system.

Figures 2a) and 2b) below show membership function graphs for fuzzy mode parameters $\tilde{x}_1$ *and* $\tilde{x}_2$, constructed using the Fuzzy Logic Toolbox.

Figure 3 shows the membership function graphs for the output parameter $\tilde{y}_1$ constructed using the Fuzzy Logic Toolbox.



a) b)

a) $\tilde{x}_1$ – temperature in column C-401 with benzene; b) $\tilde{x}_2$ pressure in the benzene column C-401

Figure 2 – Membership functions of fuzzy mode parameters

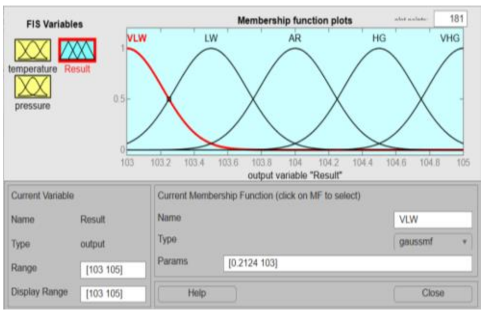


Figure 3 – Membership functions, fuzzy output parameter $\tilde{y}_1$ – average octane number of benzenes

A rule base system for a fuzzy inference system, created on the basis of a production model of knowledge representation, for evaluating the fuzzy quality indicator of benzene depending on the fuzzy values of the operating parameters of the benzene column, is presented in the form of fuzzy production rules.

Rule 1: IF «$\tilde{x}_1$ is LW» ⋁ «$\tilde{x}_2$ is LW» $THEN$ «$\tilde{y}_1$ is VLW»;
Rule 2: IF «$\tilde{x}_1$ is LW» ⋁ «$\tilde{x}_2$ is BN» $THEN$ «$\tilde{y}_1$ is VLW»;
Rule 3: IF «$\tilde{x}_1$ is BA» ⋁ «$\tilde{x}_2$ is LW» $THEN$ «$\tilde{y}_1$ is LW» ;
Rule 4: IF «$\tilde{x}_1$ is BA» ⋁ «$\tilde{x}_2$ is BN» $THEN$ «$\tilde{y}_1$ is VLW»;
Rule 5: IF «$\tilde{x}_1$ is LW» ⋁ «$\tilde{x}_2$ is NR» $THEN$ «$\tilde{y}_1$ is VLW» ;
Rule 6: IF «$\tilde{x}_1$ is AR» ⋁ «$\tilde{x}_2$ is LW» $THEN$ «$\tilde{y}_1$ is LW»;
Rule 7: IF «$\tilde{x}_1$ is BA» ⋁ «$\tilde{x}_2$ is NR» $THEN$ «$\tilde{y}_3$ is LW»;
Rule 8: IF «$\tilde{x}_1$ is AR» ⋁ «$\tilde{x}_2$ is BN» $THEN$ «$\tilde{y}_1$ is LW»;
Rule 9: IF «$\tilde{x}_1$ is AR» ⋁ «$\tilde{x}_2$ is NR» $THEN$ «$\tilde{y}_1$ is LW»;
Rule 10: IF «$\tilde{x}_1$ is LW» ⋁ «$\tilde{x}_2$ is AA» $THEN$ «$\tilde{y}_1$ is LW»;
Rule 11: IF «$\tilde{x}_1$ is AA» ⋁ «$\tilde{x}_2$ is LW» $THEN$ «$\tilde{y}_1$ is AR» ;
Rule 12: IF «$\tilde{x}_1$ is BA» ⋁ «$\tilde{x}_2$ is AA» $THEN$ «$\tilde{y}_1$ is AR» ;
Rule 13: IF «$\tilde{x}_1$ is AA» ⋁ «$\tilde{x}_2$ is BN» $THEN$ «$\tilde{y}_1$ is AR»;
Rule 14: IF «$\tilde{x}_1$ is AR» ⋁ «$\tilde{x}_2$ is AA» $THEN$ «$\tilde{y}_1$ is AR»;
Rule 15: IF «$\tilde{x}_1$ is AA» ⋁ «$\tilde{x}_2$ is NR» $THEN$ «$\tilde{y}_1$ is AR»;
Rule 16: IF «$\tilde{x}_1$ is AA» ⋁ «$\tilde{x}_2$ is AA» $THEN$ «$\tilde{y}_1$ is HG»;
Rule 17: IF «$\tilde{x}_1$ is LW» ⋁ «$\tilde{x}_2$ is HG» $THEN$ «$\tilde{y}_1$ is HG»;
Rule 18: IF «$\tilde{x}_1$ is HG» ⋁ «$\tilde{x}_2$ is LW» $THEN$ «$\tilde{y}_1$ is HG» ;
Rule 19: IF «$\tilde{x}_1$ is BA» ⋁ «$\tilde{x}_1$ is HG» $THEN$ «$\tilde{y}_1$ is HG»;
Rule 20: IF «$\tilde{x}_1$ is HG» ⋁ «$\tilde{x}_2$ is BN» $THEN$ «$\tilde{y}_3$ is HG»;
Rule 21: IF «$\tilde{x}_1$ is AR» ⋁ «$\tilde{x}_2$ is HG» $THEN$ «$\tilde{y}_1$ is VHG»;
Rule 22: IF «$\tilde{x}_1$ is HG» ⋁ «$\tilde{x}_2$ is NR» $THEN$ «$\tilde{y}_1$ is VHG»;
Rule 23: IF «$\tilde{x}_1$ is AA» ⋁ «$\tilde{x}_2$ is HG» $THEN$ «$\tilde{y}_1$ is VHG» ;
Rule 24: IF «$\tilde{x}_1$ is HG» ⋁ «$\tilde{x}_2$ is AA» $THEN$ «$\tilde{y}_1$ is VHG»;
Rule 25: IF «$\tilde{x}_1$ is HG» ⋁ «$\tilde{x}_2$ is HG» $THEN$ «$\tilde{y}_1$ is VHG»,

Where ⋁ – «and», i.e., the union operation.

If it is necessary to take into account the degrees of confidence in the truth of each sub-rule of the rule base, weight coefficients $F_i, i = \overline{1,25}$ are introduced, taking values from 0 to 1. Since all weight coefficients in the resulting rule base are equal to 1, they are not shown.

The rule base obtained above, implemented in Fuzzy Logic Toolbox, which forms the basis of the knowledge base, is shown in Figure 4.

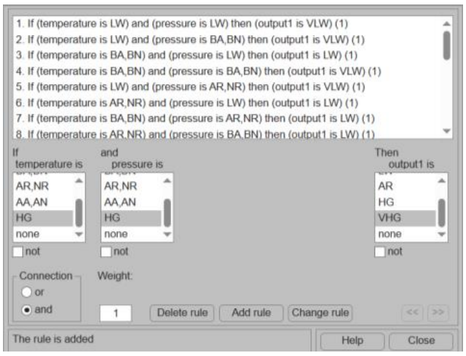


Figure 4 – Rule base for estimating the average octane number of benzenes, which is its main quality indicator

Figure 5 shows the results of visualizing fuzzy logical inference in Rule Viewer based on the created rule base, where the Input field contains the values of the mode parameters for which logical inference is implemented.

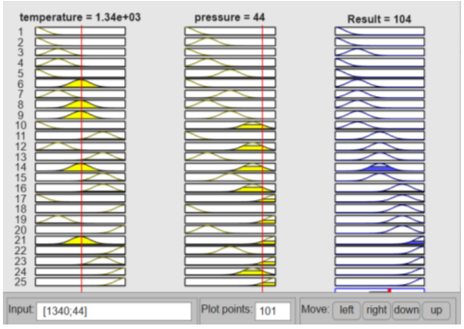


Figure 5 – Results of fuzzy logic inference visualization in Rule Viewer Fuzzy Logic Toolbox

Figure 6 below shows the results of three-dimensional visualization of fuzzy modeling in the form of the “input-output” surface of a benzene column. The resulting surface corresponds to the created rule base and allows visual control of the fuzzy modeling results.

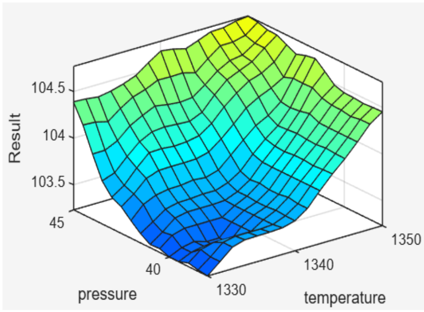


Figure 6 – Three-dimensional visualization of fuzzy modeling of a benzene column in the Fuzzy Logic Toolbox Surface Viewer window

Discussion of scientific results

The developed and described method for synthesizing linguistic models of poorly formalizable objects described with fuzzy input and output parameters is based on conditional logical inference rules using a production model of knowledge representation and operations on fuzzy sets. In this method, expert assessment techniques are used to create a rule base describing the influence of input linguistic variables on the fuzzy values of the output parameter.

Synthesized linguistic models based on the proposed method allow estimating the average octane number of benzenes from the C-401 benzene column output based on fuzzy modeling of the benzene production process using the Fuzzy Logic Toolbox and determining the C-401 operating mode that provides the maximum volume of benzene with the required quality.

Based on the results of visualizing the implementation of the rule base in Rule Viewer, shown in Figure 4, it is possible to analyze the conclusion of each rule and the results of modeling based on the defuzzification procedure. Figure 4 shows the modeling results obtained for the following operating parameters of the benzene column: temperature 1340°C; pressure 44 kg/cm^2. At these operating parameters of the benzene column, the average octane number of the benzene obtained is 104, which, according to Table 2, compiled on the basis of the current standard, means high benzene quality. It should be noted that using the Rule Viewer window of the Fuzzy Logic Toolbox to simulate the operating modes of the benzene column, i.e., by changing the fuzzy values of its operating parameters, it is possible to select the best value for the quality of the benzene produced.

Based on the results of the analysis and discussion of fuzzy modeling and the input-output surface in the Surface Viewer window (Figure 5), it can be noted that the lower the values of the operating parameters (temperature, pressure) of the benzene column, the higher the quality of benzene, since the average octane number of benzenes increases. Conversely, the higher the temperature and pressure of the benzene column, the lower the quality of the benzene. This conclusion is consistent with the established set of rules, and in practice, when managing the benzene production process, it is necessary to choose a compromise solution that maximizes the volume of benzene produced with the specified quality indicators. However, sometimes, due to the requirements of the benzene market, it is necessary to choose a benzene column operating mode that provides the required volume of benzene with the best quality indicators. Thus, based on the models, it will be necessary to solve the problem of choosing a compromise solution, taking into account market demand for the volume of benzene and its quality, since these criteria are contradictory.

Conclusion

The paper proposes a new method for synthesizing linguistic models of poorly formalizable objects, which allows for the effective modeling of such objects with fuzzy input and output parameters. Based on the proposed method, linguistic models have been synthesized that allow for the evaluation of the main quality indicator of benzene and the modeling of the process of producing high-quality benzene in a fuzzy environment.

The research yielded the following main results:

– A method was proposed for synthesizing linguistic models of complex technological objects with fuzzy input and output parameters, allowing their operating modes to be modeled and optimized.

– Based on the proposed method, linguistic models were synthesized to estimate the average octane number of benzene and to perform fuzzy modeling of the operating modes of a benzene column in order to determine its effective operating mode that ensures the required benzene quality.

– Based on the Delphi method, logical rules of conditional inference, and a production model of knowledge representation, a rule base was created for fuzzy modeling of benzene column operating modes in Fuzzy Logic Toolbox.

The novelty of the results lies in the development of a new effective method for synthesizing linguistic models of complex technological objects in a fuzzy environment for fuzzy modeling and optimization of their operating modes.

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БЕНЗОЛДЫҚ КОЛОННА ШЫҒЫСЫНДАҒЫ БЕНЗОЛДЫҢ САПАЛЫҚ КӨРСЕТКІШТЕРІН БАҒАЛАУ ҮШІН ЛИНГВИСТИКАЛЫҚ МОДЕЛЬДЕРІН ҚҰРУ

Қазіргі уақытта мұнай-химия өнеркәсібінің қарқынды дамуына және оның өнімдеріне сұраныстың артуына байланысты сапалы бензол өндіру нысандарының өнімділігін олардыің модельдері негізінде арттыру өзекті ғылыми-практикалық міндетке айналды. Өндірісте бензол сапасының негізгі көрсеткіштері бензол өндіру процесін басқаратын оператор-технологлардың және зауыт зертханасы мамандарының тәжірибесі мен біліміне сүйене отырып, айқынсызда бағаланады. Бұл мақалада бензолдық колонна сияқты нашар формализацияланатын, айқын емес кіріс, шығыс параметрлерімен сипатталатын технологиялық нысандардыжұмыс режимдерін модельдеуге, оптимизациялауға мүмкіндік беретін лингвстикалық модельдерін синтездеу тәсілі ұсынылған. Ұсынылған тәсіл негізінде зерттеу нысаны болып табылатын Атырау мұнай өңдеу зауытының бензолдық колоннасында өндірілетін бензолдың негізгі сапа көрсеткішін бағалаудың лингвистикалық модельдері синтезделді. Алынған лингвистикалық модельдер – ережелер базасы арқылы Fuzzy Logic Toolbox қосымшасынлда зерттелетін бензол колоннасының әртүрлі жұмыс режимдерін айқынсыздықта модельдеу және оптимизациялау жүргізілді. Нәтижесінде жоғары сапалы бензолдың көлемін максимизациялауға мүмкіндік беретін бензолық колоннаның оптималды жұмыс режимі анықталды. Айқынсыздықта күрделі технологиялық нысандардыің лингвистикалық модельдерін синтездеу үшін ұсынылған тәсілдің жаңалығы мен маңыздылығы кіріс және шығыс параметрлері айқын емес нысандардың тиімді лингвистикалық модельдкерін құруға мүмкіндік

беруінде. Зерттеу нысанының құрылған лингвистикалық модельдерінің практикалық маңыздылығы айқынсыздықта модельдеу арқылы оның жұмыс режимдерін айқын емес ортада оптимизациялауда.
Түйін сөздер: *бензолдық колонна, айқын емес емес модельдеу, оптимизациялау, лингвистикалық модельдер, бензол өндіру процесі.*

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РАЗРАБОТКА ЛИНГВИСТИЧЕСКИХ МОДЕЛЕЙ ДЛЯ ОЦЕНКИ КАЧЕСТВЕННЫХ ПОКАЗАТЕЛЕЙ БЕНЗОЛА НА ВЫХОДЕ БЕНЗОЛЬНОЙ КОЛОННЫ В НЕЧЕТКОЙ СРЕДЕ

В настоящее время в связи интенсивным развитием нефтехимической отрасли и ростом спроса на ее продукты актуальной научно-практической задачей стала повышение производительности объектов производства качественного бензола на основе их моделей. На практике основные показатели качества бензола оцениваются нечетко на основе опыта, знаний операторов-технологов, управляющие процессом производства бензола и специалистов заводской лаборатории. В работе предложен метод синтеза лингвистических моделей плохо формализуемых технологических объектов, как бензольная колонна, с нечеткими входными и выходными параметрами, позволяющий моделировать и оптимизировать режимов их работы в нечеткой среде. На основе предложенного метода разработаны лингвистические модели оценки основного качественного показателя бензола, производимого в бензольной колонне Атырауского нефтеперерабатывающего завода, являющейся объектом исследования. На основе разработанных лингвистических моделей − базы правил в Fuzzy Logic Toolbox проведено нечеткое моделирование различных режимов работы исследуемой бензольной колонны и оптимизация ее режиме. В результате определен оптимальный режим ее работы бензольной колонны, позволяющий максимизировать объем и бензола с ее выхода с наилучшим качественным показателям. Новизна и важность предложенного метода синтеза лингвистических моделей сложных технологических объектов в нечеткой среде, в том, что позволяет разработать эффективных лингвистических моделей объектов с нечеткими входными и выходными параметрами. Практическая значимость разработанных лингвистических моделей исследуемого объекта заключается в оптимизации ее режимов работы в нечеткой среде на основе нечеткого моделирования.
Ключевые слова: *бензольная колонна, нечеткое моделирование, оптимизация, лингвистические модели, процесс производства бензола.*

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УНИВЕРСАЛЬНЫЙ ТРАНСФОРМЕРНЫЙ ФРЕЙМВОРК ДЛЯ АНАЛИЗА И ГЕНЕРАЦИИ ТЕКСТА

Аннотация: *В статье предложен универсальный мультимодальный фреймворк для решения трёх задач обработки естественного языка: распознавания сарказма, сентиментно-ориентированной генерации описаний изображений и контекстного нейросетевого машинного перевода с использованием механизма reranking. Архитектура включает специализированные энкодеры (BERT, RoBERTa, ViT), кросс-модальные механизмы внимания и контрастивное обучение, что обеспечивает адаптацию к различным типам входных данных и семантических задач. Эксперименты продемонстрировали улучшение метрик BLEU, METEOR, F1 и NER по сравнению с базовыми моделями. Отдельное внимание уделено устойчивости модели при работе с редкими словами и именованными сущностями. Полученные результаты подтверждают эффективность предложенного подхода в условиях ограниченных данных и мультимодальной сложности. В условиях стремительного роста мультимедийного контента и экспрессии пользователей в социальных сетях, мультимодальные модели – объединяющие текст, визуальные и стилистические признаки – становятся ключевым направлением в развитии когнитивных ИИ-систем. В частности,*