https://doi.org/10.33271/nvngu/2022-4/112

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APPLICATION OF MATHEMATICAL MODELLING METHODS IN OIL PRODUCTION MANAGEMENT

Purpose. To assess the effectiveness of the practical application of mathematical modelling methods of the operation principles of oil production management systems in a fuzzy environment and the main aspects of their application in oil production.

Methodology. The basis of the methodological approach in this study is a combination of methods of quantitative and qualitative analysis of the basic principles of the development of mathematical models for managing oil production processes in a fuzzy environment.

Findings. The authors investigated the available methods of mathematical modeling in order to select the optimal possibilities for creating mathematical models. A qualitative assessment of the effectiveness of the practical application of methods of mathematical modeling of the principles of operation of oil production management systems in a fuzzy environment was formulated. The main aspects of application of methods of mathematical modeling directly in the process of oil production were established.

Originality. A fuzzy approach is proposed for solving the problem of multi-criteria optimization in the development of a field and oil production, in which the task is set and solved in a fuzzy environment without previously converting them to equivalent clear tasks. This ensures the correctness and efficiency of the solution by increasing the adequacy of the description of the problem in a fuzzy environment.

Practical value. The results obtained and the conclusions formulated on their basis are of considerable practical importance for employees of research institutes of the oil industry responsible for the development of effective methods of mathematical modelling of oil production process control systems and for employees of oil companies whose professional duties include the introduction of the mentioned mathematical models in oil fields.

Keywords: *mathematical models, oil industry, oil production management*

Introduction. The effective functioning of the oil-producing industry is the main condition for the development of the economies of many countries of the world. Recently, the share of oil reserves confined to reservoirs with hard-to-recover oil reserves in the world has been gradually increasing. The efficiency of oil development and production from such fields by conventional methods is relatively low, which necessitates the search for new, more effective and rational solutions to improve the overall quality of oil production and the volume of oil produced [1]. Under these conditions, the prospects for the development of the oil industry are determined by a number of important factors, namely:

- the development and application of effective technological processes to increase the volume of oil extracted from reservoirs;
- the maximum use of the capabilities of each production and injection well in accordance with the potential of the production facility;
- effective forecasting and regulation of the well stock in oil production based on a mathematical model using automated systems;
- optimisation of oil production processes in the conditions of fuzzy initial information, which are often observed in practice [2].

One of the urgent tasks of oil production is to increase the efficiency of using the fund of oil wells using automated systems based on mathematical models. Ensuring the normal functioning of the well fund is conditioned by the improvement of the organisation, equipment, and technology of oil production, the repair, preventive maintenance, and field research at a given frequency throughout the well stock [3, 4].

The development of the latest software models describing the functioning of oil companies directly in the context of the implementation of oil production processes is one of the most promising areas of development in the oil industry [5, 6]. To date, there are a number of problems related to the search for optimal ways to find and implement effective mathematical models that can qualitatively describe the management of oil production processes in a fuzzy environment [7]. Their timely resolution is of great practical importance for optimising the main aspects of oil production and finding optimal opportunities for the implementation of these mathematical models.

The methods of geological and hydrodynamic modelling based on modern software are quite effective analytical tools that allow monitoring and regulating the main processes of oil field development and oil production [8]. Thus, the creation of mathematical models that reflect the current state of the reservoir system and its modifications directly under the influence of oil production processes allows for effective monitoring of the main aspects of these processes, which is of key importance when it is necessary to make timely decisions to ensure the high quality of the functioning of the oil field [9]. Geological and hydrodynamic modelling allows obtaining a qualitative solution to a number of problems related to the development of oil fields and improving the overall efficiency of oil production. This applies both to the calculations of the main and residual oil reserves and also concerns the issues of substantiating the methodology and principles of oil extraction and forecasting oil production volumes after specified time intervals.

Oil production is a complex production process that considers many composite stages. The proper execution of the sequence of technological operations at each stage of oil production ensures the maximum effect from the entire process, which is expressed in obtaining high-quality oil and maintaining the required production volumes. The maximum effect can be achieved only with high-quality compliance with all technological requirements put forward for this process, otherwise, problems may occur at any stage of the work [10]. Therewith, the process of pumping oil out of the well is the main technological task that has a sufficient degree of complexity and carries risk.

The deep method of oil production is a priority in most countries of the former USSR, providing more than half of the total volume of oil produced. Therewith, the key aspect of this process is the practical application of submersible centrifugal pumps as standard equipment for ensuring the proper intensity of oil production. It is mandatory to maintain the proper level of oil production in the well to avoid its premature draining when pumping oil products from the well with various natural mixtures that can adversely affect the operation of the unit as a whole [11]. The cost of repairing equipment in case of its possible breakdown is extremely high and comparable to the cost of new units, therefore, issues of ensuring the safety of equipment for pumping oil should be given priority at any stage of planning this process. The procedure for describing a well as an object of management is extremely complex from a technological standpoint and requires timely consideration of a large number of factors that are of key importance for ensuring the quality of this process, which is not always advisable and necessary.

Indicators of oil production volumes are of considerable importance in the context of ensuring the stable functioning of the country's economy. Oil prices determine the receipt of export duties on hydrocarbons and provide a constant inflow of currency to the countries by increasing the volume of export supplies of oil and petroleum products. The forecast of oil price growth is considered when compiling the state budget, in terms of the impact of balance sheet items on forecasting [12]. In this context, the correct organisation of oil production and export supplies ensures the consistent implementation of all aspects of this process, which is facilitated by the use of mathematical modelling methods in the development of management systems for oil production and its supplies abroad.

Compilation of a qualitative model of an oil field involves the consistent development of a certain geological framework, considering the individual features characteristic of a particular region of oil production. This framework is limited by geological velocities and periods of relaxation of geological layers, in combination with the problem of constructing their interfaces with macroscopic screening processes to implement subsequent predictive calculations. Analysis of the processes of oil field development in combination with an assessment of the prospects for its expansion and increase in oil production require timely information about the current state of the oil layers and specific measures to increase oil production. In this context, the implementation of mathematical modelling methods for the evolutionary processes that take place during the extraction of oil from reservoirs is essential [13]. In addition, the methods of mathematical modelling that are being developed today provide a high-quality and timely solution to the problems of forcing adapted reservoir deposits along with subsequent analyses of the probability of errors in the estimation of design parameters. Moreover, modern mathematical models for managing oil production processes allow solving issues of assessing the quality of oil production and forecasting the time of depletion of reserves of specific fields, which is extremely important from the standpoint of planning the functioning of the oil field.

The purpose of this study is to assess the effectiveness of the practical application of mathematical modelling methods of the operation principles of oil production management systems in a fuzzy environment and the main aspects of their application in oil production. The results obtained are of considerable importance for the overall improvement of the quality of oil production and increase in the efficiency of the functioning of oil-producing enterprises that use mathematical models for managing oil production processes in a fuzzy environment.

Materials and methods. With the development of mathematical modelling methods and computer technologies, the most effective and promising methods for solving oil production problems have become mathematical modelling methods and optimization of oil production processes based on modern computer technology. Such an approach to solving the problem of research, optimization, and control of technological objects and oil production processes allows us to quickly simulate the operating modes of technological objects and determine the optimal modes according to the selected criteria. For this, it is necessary to develop mathematical models of oil production processes and algorithms for their optimization. Then the developed models and algorithms are implemented in the form of a software package, which forms the basis of a computer system for optimizing and controlling oil production processes. To determine the effective solution to the problems included in the subject of this research work, it is necessary to consistently form an adequate mathematical model of the process of functioning of the well stock, which makes it possible to simulate various situations.

The basis of the methodological approach in this study is a combination of quantitative and qualitative approaches to the consideration of the issues under study. To perform qualitative research and build mathematical models of oil development and production processes, analytical methods were used to build deterministic models and statistical, probabilistic methods for collecting and processing statistical data. For a fuzzy description of optimisation in a fuzzy environment, methods for developing expert estimates and fuzzy set theories were used. Statistical data are collected based on the materials of the reports of the Joint-Stock Company "CNPC-Aktobemunaygaz" on the oil fields "Kenkiyak" and "Akzhar". The collection of fuzzy information about the object and the process of oil production was conducted based on expert assessment methods, in particular, the Delphi method. The Fuzzy Logic Toolbox applications of the MatLab system were used to construct the membership function of linguistic variables of oil production processes.

The theoretical basis of this study is relevant available findings of domestic and a number of foreign researchers devoted to issues of creating high-quality mathematical models for managing oil production processes in a fuzzy environment. All the findings of foreign researchers have been translated into English to create the most objective and qualitative picture of the study and to facilitate the perception of the information provided in it. The general scheme of work is shown in Figure.

This study was conducted in three stages:

1. At the first stage of this study, a theoretical investigation of publications on the prospects for the development of methods for mathematical modelling of oil production management systems in a fuzzy environment was conducted. Based on the theoretical basis of the study, a quantitative analysis of the available mathematical modelling techniques was performed to select the optimal possibilities for creating mathematical models, with a view to their subsequent application in the practice of managing oil production processes.

2. At the second stage, a qualitative analysis of methods for constructing deterministic models was conducted along with statistical, probabilistic methods for collecting and processing statistical information. In addition, methods for creating expert assessments and fuzzy set theory were used. Therewith, at this stage, the preliminary results were compared with the re-

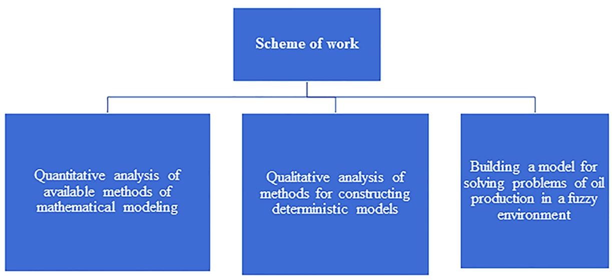

Fig. General scheme of work

sults obtained by other researchers involved in the development of problems related to the issues under study.

3. At the third stage, final conclusions were formulated, reflecting the results obtained and summarising the entire complex of research activity performed.

Results. Let us consider an approach to the development of mathematical processes of oil production, which form the basis of the software for automated systems for forecasting and regulating the well stock based on modern computer technology. To implement this approach, it is allowed to use the principles of the theory of Markov chains.

Categories of fuzziness in oil production can be conditionally divided into simple, complex, and difficult-to-formalise. The first kind includes such categories as "low porosity", "high permeability", which are sets that can be easily ordered. When implementing such an approach, the multiplicity of values can be determined based on the peculiarities of considering both local and global constraints, their coordination with the characteristic ambiguity and fuzziness in design solutions, which has a decisive effect in an integrated approach to forecasting.

Both internal and external factors are sources of uncertainty in the forecast of oil development and production. Some features of the structure and subtleties in the behaviour of the deposit may be lost during the construction of the model. On the other hand, very often external factors, such as the specific features of oil and gas collection and treatment systems and changes in the goals and means of developing deposits cannot be considered in the model. That is why, in our study, we did not consider external factors (technological and economic uncertainty), but internal (geological) ones. At the same time, the "depth of occurrence" is meant: the geometry of the deposit and its parameters; seismic interpretation and well logging; oil reserves.

The use of precise mathematical solutions, in particular analytical ones, does not guarantee accurate and final results, just as an increase in the number of nodes (lattice blocks) in numerical methods does not automatically increase the final accuracy of calculations. On the other hand, unsatisfactory forecasting results do not necessarily stem from a poor geological model. The main sources of uncertainty in oil development and production include geological and field data; reservoir description; model discretisation; mathematical calculation errors; external factors (Table).

For the convenience of further presentation, the basic concepts of the theory of fuzzy sets are involved. The main approach to the formalisation of fuzziness is to use the "Fuzzy Set" (FS) concept. Such a set is formed by introducing a generalized concept of membership, i. e., by expanding the two-element set of values of the characteristic function {0,1} to the continuum [0,1]. Therewith, the transition from the complete belonging of an object to its complete non-belonging occurs gradually and the belonging of an element to a set is expressed by a number from the interval [0,1]. A fuzzy set $\tilde{A} = \{(x, \mu(x))\}$ is defined mathematically as a set of ordered pairs composed of elements of the universal set X, and the corresponding degrees (functions) of membership $\mu(x)$, or directly in $\mu(x)$: $X \to [0, 1]$ form.

The membership function $\mu(x)$ refers to some improbable subjective measurement of fuzziness. Some researchers state that the membership function $\mu_A(x)$ is a conditional probability of examining an event during observation (x). The value of the membership function $\mu_A(x)$ for each element $x \in X$ on the segment [0, 1] will be called the degree of membership of element x to the fuzzy set A.

Table

Uncertainty in forecasting oil deposits and their development

Geological	Technological	Economic
Geometry of the deposit and its parameters	Drilling arrangement	Oil cost
Interpretation of seismics and geophysical studies of wells	Operational parameters	Inflation
Oil reserves	Some parameters of the mining process	

Fuzzy subsets $\tilde{A}$ and $\tilde{B}$ should be considered as a parameter: $\tilde{A}$ – "large reservoir depth"; $\tilde{B}$ – "small reservoir depth", sets $H = \{h_1, h_2, h_3, h_4, h_5\}$ where $h_1 = 500$; $h_2 = 1000$; $h_3 = 1500$; $h_4 = 2500$; $h_5 = 3500$ m, then the fuzzy subset $\tilde{A}$ and $\tilde{B}$ can be written as $\tilde{A} = \left\{ \left\langle \frac{0{,}05}{h_1} \right\rangle ; \left\langle \frac{0{,}1}{h_2} \right\rangle ; \left\langle \frac{0{,}5}{h_3} \right\rangle ; \left\langle \frac{0{,}9}{h_4} \right\rangle ; \left\langle \frac{1{,}0}{h_5} \right\rangle \right\}$;

$\tilde{B} = \left\{ \left\langle \frac{1{,}0}{h_1} \right\rangle ; \left\langle \frac{0{,}9}{h_2} \right\rangle ; \left\langle \frac{0{,}6}{h_3} \right\rangle ; \left\langle \frac{0{,}1}{h_4} \right\rangle ; \left\langle \frac{0{,}01}{h_5} \right\rangle \right\}$. Therefore, operations can be performed on these fuzzy sets: $\neg$ – negation, $\cup$ – union, $\cap$ – intersection, etc., in accordance with formulas from the theory of fuzzy sets.

It is advisable to assume that there are matrices of relations $U \to V$ (or $U \times V$) and $U \to W$ (or $U \times W$), which can be the result of an expert survey of specialists in field development and oil production. The paired relationships of elements reflect the degrees of belonging of pairs $\langle u, v\rangle \in U \times V$ and $\langle v, w\rangle \in V \times W$ to $\tilde{A}$ and $\tilde{B}$ fuzzy sets, respectively. For example

$$\tilde{A} = \begin{pmatrix} \mu_A\langle u_1, v_1\rangle \mu_A\langle u_1, v_2\rangle \\ \mu_A\langle u_2, v_1\rangle \mu_A\langle u_2, v_2\rangle \end{pmatrix} = \begin{pmatrix} 0.5 0.7 \\ 0.8 0.2 \end{pmatrix};$$

$$\tilde{B} = \begin{pmatrix} \mu_A\langle v_1, w_1\rangle \mu_A\langle v_1, w_2\rangle \\ \mu_A\langle v_2, w_1\rangle \mu_A\langle v_2, w_2\rangle \end{pmatrix} = \begin{pmatrix} 0.3 0.4 \\ 0.9 0.6 \end{pmatrix}.$$

They can be written otherwise as

$$\tilde{A} = \left\{ \begin{matrix} \left\langle \frac{0.5}{\langle u_1, v_1\rangle} \right\rangle ; \left\langle \frac{0.8}{\langle u_2, v_1\rangle} \right\rangle ; \left\langle \frac{0.7}{\langle u_1, v_2\rangle} \right\rangle ; \\ ; \left\langle \frac{0.2}{\langle u_2, v_2\rangle} \right\rangle \end{matrix} \right\};$$

$$\tilde{B} = \left\{ \begin{matrix} \left\langle \frac{0.3}{\langle v_1, w_1\rangle} \right\rangle ; \left\langle \frac{0.9}{\langle v_2, w_1\rangle} \right\rangle ; \left\langle \frac{0.4}{\langle v_1, w_2\rangle} \right\rangle ; \\ ; \left\langle \frac{0.6}{\langle v_2, w_2\rangle} \right\rangle \end{matrix} \right\}.$$

The degrees of belonging of different pairs are determined

$$\mu_{A \cdot B} < u_1, w_1 \geq (\mu_A\langle u_1, v_1\rangle \,\&\, \mu_B\langle v_1, w_1\rangle \vee$$
$$\vee (\mu_A\langle u_1, v_2\rangle \,\&\, \mu_B\langle v_2, w_1\rangle) = (0.5 \,\&\, 0.3) \vee (0.7 \,\&\, 0.9) = 0.7;$$
$$\mu_{AB} < u_2, w_1 = (\mu_A\langle u_2, v_1\rangle \,\&\, \mu_B\langle v_1, w_1\rangle) \vee$$
$$\vee (\mu_A\langle u_2, v_2\rangle \,\&\, \mu_B\langle v_2, w_1\rangle) = (0.8 \,\&\, 0.3) \vee (0.2 \,\&\, 0.9) = 0.3;$$
$$\mu_{AB} < u_1, w_1 \geq (0.5 \,\&\, 0.4) \vee (0.7 \,\&\, 0.6) = 0.6;$$
$$\mu_{AB} < u_2, w_2 \geq (0.8 \,\&\, 0.4) \vee (0.2 \,\&\, 0.6) = 0.4.$$

In the final expressions, to simplify the notation, the signs ~ (tilde), meaning the fuzziness of the sets A and B, are not indicated.

In this case, the composition of fuzzy sets $\tilde{A} \cdot \tilde{B}$ is nothing more than the *maxmin* product of matrices $\tilde{A}$ and $\tilde{B}$

$$\tilde{A}\tilde{B} \quad \tilde{A} \cdot \tilde{B} = \begin{pmatrix} 05 07 \\ 08 02 \end{pmatrix} \cdot \begin{pmatrix} 03 04 \\ 09 06 \end{pmatrix} = \begin{pmatrix} 07 06 \\ 03 04 \end{pmatrix}.$$

In the maximin product of matrices $\tilde{A}$ and $\tilde{B}$, instead of a sequence of addition and multiplication operations, disjunction ($\vee$) and conjunction (&) operations are used, respectively. The concept of the degree of equality $\mu(\tilde{A}, \tilde{B})$ of fuzzy sets $\tilde{A}$

and $\tilde{B}$ in U is considered to introduce the concepts of fuzzy equality of fuzzy sets, which is defined through the logical operations of equivalence (↔) and conjunction as

$$\mu(\tilde{A},\tilde{B}) = \underset{u\in U}{\&}\left[\mu_A(u) \leftrightarrow \mu_B(u)\right] =$$

$$= \underset{u\in U}{\&}\left\{\begin{array}{c} \min\left[\left(\max(1-\tilde{A},\tilde{B}),\max(1-\tilde{A},\tilde{B})\right)\right] \\ = \min\limits_{u\in U}\left\{\min\left[\max(1-\tilde{A},\tilde{B}),\max(1-\tilde{A},\tilde{B})\right]\right\} \end{array}\right\}.$$

A fuzzy relation $\tilde{f} = (U,\tilde{A})$ is given on a set of geological parameters $U = \{u_1, u_2, u_3, u_4, u_5\}$. The subset "geological parameters strongly influencing the development process" is a fuzzy subset $\tilde{A}$ in u_2. In this case, graph $\tilde{A}$ can be represented as

$$\tilde{A} = \left\{\begin{array}{c} \left\langle\frac{0.4}{\langle u_1,u_2\rangle}\right\rangle;\left\langle\frac{0.8}{\langle u_1,u_5\rangle}\right\rangle;\left\langle\frac{1.0}{\langle u_2,u_3\rangle}\right\rangle;\left\langle\frac{0.1}{\langle u_2,u_4\rangle}\right\rangle; \\ \left\langle\frac{0.9}{\langle u_3,u_1\rangle}\right\rangle;\left\langle\frac{0.3}{\langle u_4,u_5\rangle}\right\rangle;\left\langle\frac{0.5}{\langle u_5,u_2\rangle}\right\rangle \end{array}\right\}.$$

The degrees of affiliation $\mu_A\langle u_i, u_j\rangle$ reflect the experts' opinion regarding the magnitude of the influence of the geological parameter u_i on u_j during the development process.

The fuzzy correspondence is

$$\tilde{F} = (U,V,\tilde{B}),$$

where $U = \{u_1, u_2, u_3, u_4\}$ is a set of geological parameters, and $V = \{v_1, v_2, v_3\}$ is a set of expert developers. The fuzzy graph of the fuzzy correspondence is given as

$$\tilde{B} = \left\{\begin{array}{c} \left\langle\frac{0.9}{\langle u_1,v_1\rangle}\right\rangle;\left\langle\frac{0.6}{\langle u_1,v_3\rangle}\right\rangle;\left\langle\frac{0.1}{\langle u_2,v_3\rangle}\right\rangle;\left\langle\frac{0.5}{\langle u_3,v_1\rangle}\right\rangle; \\ ;\left\langle\frac{0.4}{\langle u_3,v_2\rangle}\right\rangle;\left\langle\frac{0.2}{\langle u_4,v_3\rangle}\right\rangle \end{array}\right\},$$

where the degrees of affiliation $\mu_{\tilde{B}}\left\langle u_i, v_j\right\rangle$ reflect, for example, the degree of importance of the geological parameter u_i according to the expert v_j.

The rule of absolute preference should be considered a priori, since it was established that y_i option is more preferable than y_j option if this preference is determined by all the estimated parameters $y_i \geq y_j \Leftrightarrow \forall k r_k(y_i) \geq r_k(y_j)$, where $r_k(y)$ is the rank estimate of y by the k^{th} parameter. The set of field development options that are not expressed in any way by the rule of absolute preference can be defined as Pareto optimal development options that need to be found and established. In this context, the idea of the fuzzy system design methodology is of great importance, within which all design tasks are considered in a fuzzy formulation and design solutions are determined based on the fullest satisfaction of the set fuzzy and contradictory design goals.

Discussion. The management of oil production in the context of maintaining the planned production volumes while monitoring the cyclicity and quality of this process is of decisive importance from the standpoint of the prospects for the development of this economic sector and the activities of oil companies. The creation of mathematical models describing the operation of control systems for oil production in a fuzzy environment contributes to its optimisation and the growth of the overall quality of the organisation of oil production, which improves economic planning and has a beneficial effect on the economy of the entire state [14]. Therefore, due attention should be paid to the task of creating mathematical modelling methods to ensure the functioning of oil production control systems in a fuzzy environment.

The specificity of the oil production sector is that it implies the imposition of certain restrictions on the course of pumping out the volumes of oil specified by preliminary calculations from a well in the presence of geological problems that carry a high probability of production problems in case of violation of oil production technology in a fuzzy environment or violation of the technology for pumping oil from a well at the field in general [15]. This conditions the urgent need for the development of a high-quality mathematical model for managing oil production in a fuzzy environment, considering all the accompanying factors that determine both the geological features of the terrain in the production region and the nature of work on the development of the field and the withdrawal of oil in the conditions of one particular field.

To date, modern oil companies have not yet paid due attention to the development and practical implementation of mathematical models in activities directly related to the development of oil fields and quality assurance of oil production processes from the standpoint of managing the progress of oil production. As a rule, oil production is conducted in an open way, considering the periodic updating of the equipment fleet at a particular field and the improvement of the skills of maintenance personnel at specific oil production sites [16]. The processes of oil production in a fuzzy environment suggest a more rational construction of mathematical modelling techniques, considering the main features of the equipment used and specific technological solutions that ensure the cyclicity and continuity of this process. Moreover, personnel training is also essential, since well-trained employees are able to make the necessary changes in a timely manner in case of non-standard situations associated with the potential danger of an accident or disruption of work [17]. Therefore, the development of qualitative mathematical models describing all possible aspects of the implementation of oil production processes at the field and the management of this process involves consistent consideration of all factors that are of key importance from the standpoint of the efficiency of the oil production in each case.

Modern mathematical models for managing oil production processes in a fuzzy environment are created using software tools that describe the main patterns that are important in the context of the qualitative organisation of oil production at specific fields. Mathematical modelling of oil production processes from field development to oil recovery from reservoirs with rise to the surface, with a sufficient degree of accuracy in the development of these models, can ensure high accuracy in the implementation of all tasks of the oil production and guarantee the uninterrupted operation of this process at all stages [18]. Therewith, special attention should be paid to the issues of maintaining the required quality standards of the extracted raw materials and preserving their reserves directly in the well, considering the pre-programmed production rates. Otherwise, the premature depletion of oil reserves at the field will cause problems for the entire industry, since the environmental friendliness of oil-producing companies which destroy the environmental situation in the regions of oil development will be put at risk.

In general, scientific research [5, 6], devoted to the development of mathematical models for controlling oil production processes in a fuzzy environment, provide the formation of clear ideas about the prospects for their creation and practical application in matters of ensuring high quality control of oil production processes [7, 10], which is of fundamental importance for the functioning modern oil fields and opens up new opportunities for the entire oil industry. High-quality development of mathematical descriptions and mathematical models for forecasting and regulating the well stock is necessary to ensure that the proper cyclicity of the flow of oil production processes is maintained and the existing natural oil reserves are preserved for its production and subsequent use for economic needs.

Conclusions. The conducted scientific study on the prospects for the practical use of mathematical modelling methods for the purpose of their subsequent application in the operation of oil production control systems in a fuzzy environment led to the following conclusions.

The results obtained in this research work give grounds to propose a new approach to solving the problems of optimizing field development and oil production in a fuzzy environment.

Methods of mathematical modelling make it possible to effectively solve the issues of managing oil production processes in a fuzzy environment, subject to the obligatory consideration in the created mathematical models of all the main factors that are important from the point of view of the prospects for the conservation of natural oil reserves, subject to all the basic principles of its production.

The construction of a linguistic model capable of qualitatively assessing the dependence of the efficiency of the oil production process on the depth of the oil occurrence and the porosity of the reservoir rocks is necessary to describe all the main parameters that are important for the formation of a full-fledged expert assessment as linguistic variables.

In general, the results obtained in the course of this research work can subsequently serve as a qualitative methodological basis for further scientific developments in the direction of studying the possibilities of creating mathematical models that determine the basic principles of operation of the oil production process control systems in fuzzy environment.

Acknowledgments. *This research was funded by Science Committee of the Ministry of Education and Science of the Republic of Kazakhstan (Grant No. AP08855680 – Intelligent decision support system for controlling the operating modes of the catalytic reforming unit).*

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Застосування методів математичного моделювання в управлінні видобутку нафти

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Мета. Оцінка ефективності практичного застосування методів математичного моделювання принципів дії систем управління видобутком нафти в нечіткому середовищі та основних аспектів їх застосування безпосередньо у процесі видобутку нафти.

Методика. Основу методологічного підходу становить поєднання методів кількісного та якісного аналізу основних принципів формування математичних моделей для управління процесами нафтовидобутку в нечіткому середовищі.

Результати. Досліджені доступні методики математичного моделювання з метою вибору оптимальних можливостей створення математичних моделей. Сформульована якісна оцінка ефективності практичного застосування методів математичного моделювання принципів дії систем управління видобутком нафти в нечіткому середовищі. Встановлені основні аспекти застосування методів математичного моделювання безпосередньо у процесі видобутку нафти.

Наукова новизна. Пропонується нечіткий підхід до розв'язання задачі багатокритеріальної оптимізації при розробці родовища й видобутку нафти, в якій завдання ставиться й дозволяється в нечіткому середовищі без попереднього перетворення їх до еквівалентних чітких завдань. Це забезпечує правильність і ефективність вирішення за допомогою підвищення адекватності опису завдання в нечіткому середовищі.

Практична значимість. Результати, отримані в ході виконання даного наукового дослідження, а також сформульовані на їх підставі висновки, мають практичне значення для співробітників науково-дослідних інститутів нафтодобувної промисловості, відповідальних за розробку ефективних методик математичного моделювання систем управління процесами нафтовидобутку, а також для працівників нафтодобувних компаній, у чиї професійні обов'язки входить використання згаданих математичних моделей на нафтових родовищах.

Ключові слова: *математичні моделі, нафтова промисловість, управління видобутком нафти*

The manuscript was submitted 19.11.21.