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PREDICTION OF THE WELL PERFOMANCE INDICATORS WITH THE USE OF FUZZY CLUSTER ANALYSISYS

Abstract. The article is devoted to the results of information analysis and the establishment of the relationship between factors affecting operating efficiency and performance indicators (turnaround time, pump delivery rate) using a fuzzy clustering algorithm. One of the main tasks of the oil field practice is to assess the influence of various factors on the performance of field operations and to make the right technological decisions. The reliability of the estimates and decisions made is determined by how reliably the input and output variables and their values are selected. Often there are situations when, in the presence of the same data, fundamentally different results are obtained. To find specific expressions of these dependencies and parameters characterizing them, in particular, methods of statistical data processing are used. As a result of analyzing the causes of failures of subsurface pumps, factors that influence the pump efficiency at the considered fields were found, which were subjected to a fuzzy cluster analysis, that allowed to get an idea of the influence of these factors on the performance indicators under uncertainty. A connection was obtained between the input and output variables, which can be expressed by the fuzzy rules IF-THEN.

Keywords: water cutting, liquid flow rate, turnaround time, membership function, fuzzy cluster analysis.

Introduction. One of the main tasks of the oil field practice is to assess the influence of various factors on the performance of field operations and to make the right technological decisions. The reliability of the estimates and decisions made is determined by how reliably the input and output variables and their values are selected. Often there are situations when, in the presence of the same data, fundamentally different results are obtained. To find specific expressions of these dependencies and parameters characterizing them, in particular, methods of statistical data processing are used and, ultimately, real experimental material or field observation results are replaced by obtained laws and some integral, that is, common for the entire dependence as a whole, assessment of the measure of correlation ratio. In accordance with the adopted technology, the found law in the form of equations of the relation between influencing factors and efficiency indicators is then transferred to the object under study. This path is often a source of erroneous conclusions, since in most cases the formulation of goals and constraints when making decisions to improve the efficiency of pumps and field operation in the presence of multi-factorality, multi-criteria are fuzzy, in a word, all this requires the use of an appropriate apparatus.

Review of recent studies. When drilling wells, we have to deal with various parameters inherent in the oil reservoir as a complex system. One of the hardest problems in this case is the classification and clustering of this amount of information, as well as the selection of the most important data. The theory of fuzzy sets is successfully used to solve this problem in the development of fields and in decision-making.

In [1], fuzzy information about hydrocarbon deposits is considered as a situation that arose due to physical and linguistic uncertainty. Physical uncertainty arises due to the impossibility of determining the necessary physicochemical, mechanical, geological and technological parameters at each point of complex systems. As the author notes, information about the geological and technical system is limited and does not fully cover the entire system. In addition, the measurement error and its subsequent interpretation contribute to the physical uncertainty of the quantitative estimates. The linguistic uncertainty of the qualitative parameters is due to the multiplicity and ambiguity of meanings and connections in the specialists' and experts' languages [1]. In the noted work it is considered that the quantitative and qualitative characteristics of a complex geological and technical system are fuzzy. In this regard, the author explores ways of operating a virtual field.

As noted in [2], a fuzzy situation can be of three types. In the fuzzy situation of the first type, alternatives from the set Ω are fuzzily described, that is, the properties of the alternatives can be assessed only at a qualitative level. The words "good", "bad", "fast", "slow", "many", "little" can be used as such assessments. The task of making a decision in this situation is to choose from the set Ω of an alternative that corresponds to some ideal more than any other alternative. To choose such an alternative, it is necessary to establish the degree of correspondence of each property of the analyzed alternatives to a similar property of an ideal. And then you should choose an alternative that has the best degree of compliance with the ideal. In a fuzzy situation of the second type, the conditions for determining the optimality principle are not clearly defined, that is, it is not clear with which of the known ideals alternatives should be compared. Such a situation arises when there can be several ideals, but the choice of one or another ideal depends on the conditions in which the decision is made. But these conditions themselves are fuzzy. In this case, the task of making a decision is to find out which of the possible situations is most likely. In the fuzzy situation of the third type, the optimality principle itself is not clearly defined, that is, the ideal with which alternatives should be compared is not exactly known, since this ideal is described only on a qualitative level. In this case, the task of making a decision is to determine what is preferable: "almost certainly corresponds to" or "is often considered."

Recently, in connection with an increase in computational power, modeling has been added to the standard decision analysis approach [3]. A risk analysis based on Monte Carlo simulation is a method by which risk and uncertainty, covering the main predictable variables in solving a problem, are described using probability distributions. Arbitrary sampling in distributions performed many, possibly thousands of times, allows you to create sequential scenarios.

Works on decision making under fuzzy conditions in the oilfield practice are shown in [4-10].

In [4], the separation of operational objects based on the theory of fuzzy sets is considered. It should be noted that the oil reservoir is not a clear and unambiguously determined object, and the applicability criteria are a logical generalization of expert assessments. At the first step, an approximate description of the parameters takes place with the help of linguistic variables (for example, a collector is estimated as "low-porous", "medium-porous" and "highly porous"). At the second step, based on expert knowledge, the function of belonging to a fuzzy set of "operational object" ("non-natural", "very bad", "bad", "mediocre", "good", "very good", "excellent") is constructed. At the third step, rules (R) for allocating an operational object (OO) are defined, for example: R1 = "IF the difference in the depth of reservoir formation is insignificant, THEN layers will represent a good OO", R2 = "IF geological factors (G) are good and technological factors (T) are good, THEN OO is good ", etc.

The advantages of applying the theory of fuzzy sets when solving problems of control and monitoring the processes of operating oil and gas fields under uncertainty are shown in [5]. The calculation algorithms are given, and the results obtained when working with fuzzy values are shown on real and hypothetical data. Fuzzy logic and its potential application in solving problems related to petroleum engineering are shown in [6–8]. The most successful application of intelligent systems, especially when solving technical problems, was achieved through the use of various intelligent tools individually and as a hybrid system. As shown in [11], expert systems are artificial intelligence tools that store and implement expert opinions, methods, and rules to achieve accurate system results. Fuzzy Petroleum Prediction (FPP) was developed to prepare an expert system using expert knowledge, analysis of oil well data, and redistribution of oil fields. The data required for its application were selected from various sources. The five factors used to predict oil were: temperature, pressure, density of crude oil, gravity, and gas density. FPP was applied at thirty wells in the Daqing oilfield as a published data set and other sources and achieved amazing results by developing various fuzzy functions.

As noted in [12], according to a survey conducted among oil and gas companies in Ghana, most managers use maximax, minimal losses and expected value when making decisions under conditions of risk and uncertainty. But quantifying uncertainty is not an end in itself; eliminating or even reducing uncertainty is also not the goal. It is wrong to assume that uncertainty is reduced by simply modeling it, and making the right decisions simply requires more information [13]. Rather, the goal is to make the right decision, which in many cases requires an assessment of the corresponding uncertainties. The oil and gas industry has overlooked this goal for a long time, focusing efforts on giving decision-makers a deeper understanding of the possible outcomes that follow from important decisions [13]. In [14], the methods used to assess underground risk and volume uncertainty over the life cycle of exploration and production are considered. Although probabilistic methods are necessary for making decisions, it has been shown that they have limitations that should be understood. In borderline situations, they are difficult to justify, and non-technical factors are important when making decisions.

The advantages of taking into account the geological uncertainty when making decisions about the location of a well are estimated by comparing the results of decisions made using the theory of fuzzy sets with those made using the traditional approach using a single deterministic model [15]. In [16], fuzzy logic is used in problems of analytical modeling of enhanced oil recovery methods. Planning for the application of enhanced oil recovery methods (EORM) is a complex task that requires an integrated approach to its solution. Without optimizing the conditions for choosing technologies for implementation at a specific site, it is impossible to fully realize the capabilities of the EORM To overcome the problems arising from the use of strict limits of applicability of the methods, it is proposed to use fuzzy logic and assign reservoir objects to a class of fuzzy environments, and solving the problem of selecting the EORM - to making decisions in a fuzzy environment. Using the theory of fuzzy sets, one can quantify categorical concepts such as “very good” or “very bad”, which is especially important in tasks such as choosing an impact method, when the reservoir parameters differ in one direction or another from the applicability criteria.

In general, an analysis of accumulated research has shown the ability to solve a number of problems in an oil field, in particular, problems of modeling, decision-making, classification of objects, etc. using the theory of fuzzy sets.

Formulation of the problem. To assess the change of the pump operation parameters, it is proposed in the literature to use the delivery rate and the turnaround time.

The delivery rate and the turnaround time depend on many factors. In order to establish the influence of these factors, an analysis of information on the geological and technological characteristics of operating conditions has been carried out, which showed the impossibility of constructing statistical dependencies in this case due to its insufficiency. Recently, decision-making methods taking into account the conditions of uncertainty became widely used. One of such methods are methods of fuzzy classification.

The results of the analysis. As is known, the main problem in the operation of wells in complicated conditions is the deterioration of reliability indicators, which in turn affects the technical and economic indicators in general. The operation of pumps is influenced by numerous factors, both geological, and technical and technological.

Geological factors (gas, water, deposits of salt, paraffin, mechanical impurities, etc.) primarily characterize reservoir conditions.

Another group of factors is the factors associated with the design of a well or pump (diameters of production strings, hole curvature, pump components and parts, etc.). Naturally, all factors can be divided into factors with positive and negative effects on pump performance. To date, accumulated a large number of studies on the work of deep-well pumps in complicated conditions. As practice shows, a dry period of well operation takes up a small part of the total period and, therefore, the effect of water on the pump operation begins almost from the beginning of the well operation. The appearance of formation water in the oil is one of the main reasons worsening the performance of wells.

The appearance of formation water in oil leads to a number of complications during operation.

The operation of the pump is also affected by oil. Since it consists of active emulsifiers - asphaltenes, as well as resins, oil is prone to the formation of emulsions, which is also facilitated by clay and sand falling from the surface or from the formation. Since the viscosity and stability of the emulsion depend on the dispersion of the oil-water mixtures, and the subsurface pumps are one of the best dispersants, an emulsion is formed during the passage of fluid through the pump's working parts, the viscosity of which can increase tenfold compared to pure oil. The influence of all these factors is ambiguous, and therefore its establishment by statistical means is difficult, often impossible. In such cases, the application of the provisions of the theory of fuzzy sets allows you to establish the desired relationship.

To establish the relationship between the performance indicators of the pump and the relevant factors characterizing the operating conditions of the wells, we have classified the operating conditions according to several criteria using a fuzzy cluster analysis program, described in [17, 18]. Water cutting, fluid flow rate, mechanical impurity level and productivity factor (input variables) for Karazhanbas deposit were selected as signs for which clustering was carried out, the turnaround time and deluivery rate were taken as output variables [19].

Currently, the tasks of cluster analysis, or automatic classification, are widely used in various fields, including the oilfield business, wherever there are sets of objects of arbitrary nature. In recent years, these methods became widely used in information analysis tasks. Traditional methods of cluster analysis suggest a clear division of the original set into subsets, where each point after splitting falling into only one cluster. However, as is known, such a restriction is not always true. Often it is necessary to produce a partition to determine the degree of belonging of each object to each set. In this case, it is advisable to use fuzzy methods of cluster analysis. The tasks in this formulation attract the interest of specialists involved in oil field practice [20]. One of the most important results in studying the operation of pumps during field exploitation is the determination of the delivery rate and the turnaround time.

As a result of the program implementation, homogeneous groups of data - clusters are obtained, the results of the noted clustering are shown in table. From this table, the mutual correspondence of the input and output variables is seen.

Mutual correspondence between the input (water cutting, fluid flow rate, productivity factor, mechanical impurity level) and output (turnaround time, delivery rate) variables

Water cutting	Fluid flow rate, tn/day	Productivity factor, tn/day*MPA	Mechanical impurity level, %	Turnaround time, days	Delivery rate
low	low	low	high	low	low
			low	medium	medium
high	medium	low	low	high	high
	high	high	high	high	high
		low	medium	high	high

Conclusion. The performed cluster analysis allows to give a qualitative assessment of the influence of marked factors on the pump efficiency indicators. For example, according to the data in Table 1, if the water cutting, flow rate and productivity factor are low, the mechanical impurity level is high, then the turnaround time and delivery rate will be low. Thus, the results of the analysis allow us to formulate fuzzy rules on the principle "if ... then ...", namely:

IF the water cutting is low and the fluid flow rate is low and the productivity factor is low and the mechanical impurity level is high, THEN the turnaround time is low and the delivery rate is low.

IF the water cutting is low and the fluid flow rate is low and the productivity factor is low and the mechanical impurity level is low, THEN the turnaround time is medium and the delivery rate is medium.

IF the water cutting is high and the fluid flow rate is medium and the productivity factor is low and the mechanical impurity level is low, THEN the turnaround time is high and the delivery rate is high.

IF the water cutting is high and the fluid flow rate is medium and the productivity factor is high and the mechanical impurity level is high, THEN the turnaround time is high and the delivery rate is high.

IF the water cutting is high and the fluid flow rate is high and the productivity factor is low and the mechanical impurity level is medium, THEN the turnaround time is high and the delivery rate is high.

As a result of analyzing the causes of failures of subsurface pumps, factors that influence the pump efficiency at the considered fields have been established, which have been subjected to a fuzzy cluster analysis, that allowed to get an idea of the influence of these factors on the performance indicators under uncertainty conditions.

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АНЫҚ ЕМЕС КЛАСТЕР-ТАЛДАУДЫ ҚОЛДАНА ОТЫРЫП, ҰҢҒЫЛАРДЫ ПАЙДАЛАНУ ТИІМДІЛІГІНІҢ КӨРСЕТКІШТЕРІН БОЛЖАУ

Аннотация. Мақала анық емес кластер-талдау алгоритмін қолдана отырып ақпаратты талдау нәтижелеріне және пайдалану тиімділігі мен тиімділік көрсеткіштеріне әсер ететін факторлар арасындағы өзара байланыс орнатуға арналған (жөндеу аралық мерзім, сораптың беру коэффициенті). Мұнай кәсіпшілігі практикасының басты міндеттерінің бірі кен орындарды пайдалану тиімділігінің көрсеткіштеріне әр түрлі факторлардың әсерін бағалау және дұрыс технологиялық шешімдер қабылдау болып табылады. Бағалау мен қабылданған шешімдердің дұрыстығы кіріс және шығыс айнымалыларының қаншалықты дұрыс таңдалуымен, олардың мәндерімен анықталады. Бір деректер болған жағдайда, нәтижесінде әртүрлі нәтижелер алынған жағдайлар жиі туындайды. Осы тәуелділіктер мен оларды сипаттайтын параметрлердің нақты өрнектерін табу үшін, атап айтқанда, деректерді статистикалық өңдеу тәсілдері пайдаланылады. Тереңдік сораптардың істен шығу себептерін талдау нәтижесінде қарастырылып отырған кен орындарында сораптардың тиімділігіне әсер ететін факторлар анықталды, оларға жасалған анық емес кластер-талдау аталған факторлардың белгісіздік жағдайда тиімділік көрсеткіштеріне әсері туралы түсінік алуға мүмкіндік берді. Анық емес ЕГЕР – ОНДА ережелерімен көрсетілуі мүмкін кіріс және шығыс айнымалылары арасындағы байланыс алынды.

Түйін сөздер: сулану, сұйықтық шығыны, жөндеуаралық мерзім, тиістілік функциясы, анық емес кластер-талдау.

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ПРОГНОЗИРОВАНИЕ ПОКАЗАТЕЛЕЙ ЭФФЕКТИВНОСТИ ЭКСПЛУАТАЦИИ СКВАЖИН С ПРИМЕНЕНИЕМ НЕЧЕТКОГО КЛАСТЕР-АНАЛИЗА

Аннотация. Статья посвящена результатам анализа информации и установлению взаимосвязи между факторами, влияющими на эффективность эксплуатации и показателей эффективности (межремонтный период, коэффициент подачи насоса) с использованием алгоритма нечеткой кластеризации. Одной из главных задач нефтепромысловой практики является оценка влияния различных факторов на показатели эффективности эксплуатации месторождений и принятие правильных технологических решений. Достоверность оценок и принятых решений определяется тем, насколько достоверно выбраны входные и выходные переменные, их значения. Часто возникают ситуации, когда при наличии одних и тех же данных, в итоге получаются принципиально различные результаты. Для нахождения конкретных выражений этих зависимостей и параметров, характеризующих их, используются, в частности, приемы статистической обработки данных. В результате анализа причин отказов глубинных насосов были установлены факторы, оказывающие влияние на эффективность насоса на рассматриваемых месторождениях, которые были подвергнуты нечеткому кластер-анализу, позволившему получить представление о влиянии отмеченных факторов на показатели эффективности в условиях неопределенности. Была получена связь между входными и выходными переменными, которые могут быть выражены нечеткими правилами ЕСЛИ-ТО.

Ключевые слова: обводненность, расход жидкости, межремонтный период, функция принадлежности, нечеткий кластер-анализ.

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