ANNOTATION

of the thesis for the degree of Doctor of Philosophy (PhD) in the specialty 8D07210 - " Petroleum Engineering"

Akhmetov Duman Amanbekovich

IMPROVEMENT OF DEVELOPMENT OF FIELDS WITH HARD-TO-RECOVER OIL RESERVES BY THERMAL RECOVERY METHODS

Assessment of the current state of the scientific or scientific-technological problem under solution.

The work of many researchers who have made a great contribution to the development of the scientific foundations in this area, who have performed interesting theoretical and experimental studies devoted to the problem of increasing the efficiency of developing fields of high-viscosity oils. The efforts of these scientists have yielded interesting results from a scientific and practical point of view. The works of M.T.Abasova, D.G.Antoniadi, N.K.Baibakov, G.I.Barenblatt, A. A.Boxerman, A.R.Garusheva, A.T.Gorbunov, S.A.Zhdanova, Yu.V.Zheltova, Yu.P.Zheltova, S.T.Zakenova, S.N.Zakirova, A.Kh.Mirzajanzade, M.L. Surgucheva, T.V.Khismetova et al. Despite numerous studies in this direction, some issues still require a number of studies related to a deeper study of hard-to-recover reserves, the conditions of their occurrence as well as decision-making to improve the development efficiency of this category of fields.

In general, the analysis of the current state of knowledge of the problems associated with hard-to-recover reserves made it possible to establish the following. Creating the basis for a system that allows a comprehensive classification of hard-to-recover reserves, recognition of deposits from the standpoint of this classification, and making adequate decisions on the choice of a method stimulating the formation in the specific conditions under consideration has not been sufficiently worked out.

Basis and initial data for the development of the thesis.

To make the most correct and well-grounded technological decisions, it is necessary to analyze of geological and physical conditions and features of the field under study and factors influencing the choice of an effective technology for the production of high-viscosity oils; analysis of the current state of field development and the efficiency of using well stock in the field under consideration; analysis of the oil production dynamics and the results of steam injection across the field using the example of the field under consideration.

It is known that reservoir conditions and the fluids saturating them are a complex system with uncertainty of both random and fuzzy nature, and therefore the choice of one method or another represents a decision-making procedure in a fuzzy environment. In addition, the choice of the optimal (minimum) amount of steam that ensures the maximum oil production is also a decision-making task with fuzzy goals

and restrictions. In this regard, obtaining, analyzing information and making decisions in the mentioned conditions are of big interest and this justifies the research tasks.

The basis for the development of the thesis is the lack of a universal classification of hard-to-recover reserves and a methodological approach to decision-making taking into account the uncertainty. As the initial data for the disclosure of the research topic the geological and physical conditions and the results of the development of the Karazhanbas field were selected, where a rich experience in the implementation of thermal methods was acquired.

Justification of the research work requirement.

One of the main conditions ensuring the high efficiency of technologies used in various oil and gas producing regions and investing in their development is the classification of hard-to-recover hydrocarbon reserves and an assessment of the degree of complexity of their development. The work performed to date makes it possible to substantiate the need for research to improve the classification of fields with hard-to-recover oil and gas reserves taking into account a set of features that affect the technical, technological and economic efficiency of the field development.

Analysis of the world experience in the use of various technologies and methods of enhanced oil recovery in the fields with hard-to-recover reserves, in particular, the steam injection is the rationale for conducting research on searching and identifying the ways to improve the efficiency of thermal steam treatment technology in thick fractured formations which is very difficult due to uncertainties occurring in the decision making process.

The degree of reliability of the research results and thesis conclusions.

The reliability of the scientific provisions and thesis conclusions is substantiated by the use of modern mathematical methods of data processing and information analysis, the consistency of the results of theoretical and experimental studies with an assessment using the appropriate criteria. The problems of classification of hard-to-recover reserves, assessment of the comparative efficiency of reservoir stimulation methods are solved, the reliability of which is justified by the use of modern methods that take into account the uncertainties that reduce the quality of information.

Relevance of the topic.

As you know the share of high-viscosity oils is more than half of the world's proven reserves. There are different ways of developing hard-to-recover oil deposits of different technological and economic characteristics. The possibility of using any technology in the development of deposits is associated with the geological structure and bedding conditions. The adoption of technological decisions takes place in conditions of uncertainty, and this, in turn, requires the use of information analysis methods subject to the given circumstance, along with this also a detailed study of the conditions and methods of development, in particular, as the technological experience of extracting high-viscosity and heavy oils shows, the possibility of using the thermal extraction method. However, in addition to these methods the alternative combined technologies should also be considered. It should be noted that the complexity of the development of fields in Kazakhstan (Karazhanbas, Kenkiyak, Kalamkas) lies in difficulties to develop the deposits using traditional methods. Therefore, the use of

new technologies for the development of fields using which it was impossible to extract significant oil reserves based on traditional methods, is relevant for Kazakhstan fields.

Objective. Improving the development efficiency of hard-to-recover oil fields using thermal stimulation methods.

Object of study. The object of the study is a productive formation containing high-viscosity and heavy oil.

Subject of study. The subject of study is the processes of displacement of high-viscosity oil by heat injection.

The main objectives of the study:
- analysis of the features and classification of hard-to-recover reserves by a set of attributes;
- analysis of geological and physical conditions and characteristics of the considered field as well as factors influencing the choice of an effective technology for high-viscosity oils production;
- analysis of the current state of field development and the efficiency of using well stock in the considered field;
- analysis of oil production dynamics and the results of steam injection in the field using the example of the Karazhanbas field;
- adoption of the optimal solution when using thermal stimulation methods.

The formulated tasks and the results obtained in the course of solving them are mutually complementing each other and serve a common goal. Each subsequent section is a continuation of the previous one, which confirms the internal unity of the work which is a completed scientific research.

Problems solving methods. The tasks were solved using the methods of mathematical statistics in data processing and information analysis. When solving the problem of classification of hard-to-recover reserves, the method and the corresponding program of fuzzy cluster analysis were used. When making decisions on the choice of the best option for stimulating the reservoir, a method based on the provisions of the theory of fuzzy sets was used.

Scientific novelty:
- scientifically substantiated main provisions for creation and practical use of the methodology for classifying fields of various types (oil, oil and gas and gas) by a set of signs, which makes it possible to assess the degree of complexity of developing reserves;
- the method of classification of objects of hard-to-recover oil in Kazakhstan according to a set of features that determine the degree of difficulty of their production based on the method of fuzzy cluster analysis;
- a parameter is proposed that characterizes the degree of difficulty in recovering reserves and the dependence of the oil recovery factor on this characteristic is built;
- a quantitative assessment of the comparative technological efficiency of using well stock is provided;

- scientifically substantiated and proposed a methodology for determining the optimal volume of injected heat which ensures maximum oil production in the geological and physical conditions of fields with hard-to-recover reserves.

Provisions submitted for the defense:

The provisions are being submitted for the defense as follows:

- complex classification of oils by viscosity, density and bedding conditions using fuzzy cluster analysis;
- statistical analysis of the current state of field development and the efficiency of using well stock in the field under study;
- a method for determining the optimal volume of the injected heat which ensures the maximum oil production in the geological and physical conditions of fields with hard-to-recover reserves.

Approbation of work results. The results of the thesis and its main provisions were reported and discussed at the International Scientific and Technical Conference: "13th International Conference on Application of Fuzzy Systems and Soft Computing (ICAFS)", Warsaw, Poland, August 27-28, 2018; International School-Seminar of Young Scientists and Students, Oil & Geoecology, Baku, 3-8 December 2018; The International Scientific and Practical Conference: "Development of Science and Technology in the Development of the Subsoil of Kazakhstan" dedicated to the 90th anniversary of Academician Sh.Yessenov; International Scientific and Practical Conference: "Methods for Enhanced Oil Recovery and Stimulation of Oil Production", Aktau, Kazakhstan, April 27, 2018; International scientific-practical conference: "Modern methods of development of fields with hard-to-recover reserves and unconventional reservoirs", Atyrau, Kazakhstan, September 5-6, 2019; International scientific and technical conference: "10th International Conference on theory and application of soft computing, computing with words and perceptions - ICSCCW 2019", Prague, Czech Republic, August 27-28, 2019.

Publications and approbation of work. According to the results of the work, 15 papers were published. Publications include in leading peer-reviewed journals recommended by the science Committee of RK and in foreign scientific publications, which is included in Scopus database, WoS, RSCI, etc.

Structure and scope of work. The thesis consists of an introduction, 4 chapters, a conclusion, a bibliographic list of 102 titles, 1 application and contains 102 pages of text, 16 figures, 6 tables.

Summary of the thesis.

The introduction justifies the urgency of the problem under consideration, formulates the goal, the main tasks of research, the object and subject of research, the main provisions, shows the scientific novelty, and also outlines the practical value of the thesis.

The first section studies the current state of knowledge of the problem of hard-to-recover oil production. A review which analyzes the studies carried out over the past years by various domestic and foreign researchers is given.

The second section is devoted to the analysis of the characteristics and classification of hard-to-recover reserves by a set of attributes. As a result of the

analysis of various approaches to this problem, a rationale for the choice of classification features is provided. It is shown that these are signs that characterize the properties of oil as well as the conditions of occurrence. To solve this problem the fuzzy cluster analysis algorithm is used. Cluster analysis was carried out according to three features - oil viscosity and density as well as formation permeability. As a result of the implementation of the fuzzy cluster analysis program four classes were obtained, each of which characterizes the degree of oil extraction difficulty.

The third section presents the results of the analysis of field development information on the example of the Karazhanbas field and assessing the degree of utilization of well stocks using an indicator characterizing the degree of stability of utilization - the Gini coefficient.

The fourth section is devoted to improving the efficiency of developing hard-to-recover oil fields using thermal stimulating methods**.** The required amount of injected steam which ensures maximum oil production has been substantiated and established using the provisions of the theory of fuzzy sets.

Assessment of technical and economic efficiency.

The economic effect from the implementation of the research results is due to increased oil production and a decreased volume of injected steam.

At the end of the work, the main conclusions and recommendations are presented.