

ABSTRACT

of the dissertation for the degree of Doctor of Philosophy (PhD)
under the educational program 8D07210 – Oil and gas business

ZHAYLIYEV ABAT ORAZULY

IMPROVING THE EFFICIENCY OF DRILLING AND DEVELOPMENT OF WELLS IN DIFFICULT GEOLOGICAL CONDITIONS

Relevance of the research topic. The Morckoe field, including the Ogayskoye block, is characterized by a complex geological structure caused by depositional features, lithotype diversity, and their spatial distribution. Core samples obtained during drilling provide an opportunity to study the lithological composition and physical-mechanical properties of rocks, such as porosity and permeability, which directly affect productivity assessment and the economic feasibility of field development. Laboratory studies of core material, including the determination of porosity, permeability, and mineralogical composition, make it possible to refine the geological model and improve the accuracy of resource evaluation. A comprehensive study of the physical and lithological characteristics of the rocks of the Morckoe field and the Ogayskoye block contributes to the development of optimal technological solutions and risk reduction associated with field development.

Thus, the study of the physical and lithological structure of rocks within the Morckoe field, including the Ogayskoye block, based on laboratory core analysis, is an integral part of a systematic approach to its development. This allows for the most efficient use of the field's resource potential while minimizing environmental impacts.

A significant contribution to the study of the region was made by domestic and international scientists and industry specialists: Қаныш Сәтбаев, Ivan Gubkin, Aliyev A.A., Guliyev A.K., Veliyev F.R., Akhmedsafin U.M., Makhambetov K.M., Yerzhanov E.E., Abdullin A.A., Zholtayev G.Zh., Abetov A.E., Kadirov F.A., Gurbanov V.Sh., Yuldasheva M.G., Abdullayev, Bogdanov, Knyazev, Uzakov, Togayev I.S., Maslov V.V., Goryunova L.F., Gibshman N.B., Kalmenov M.D., Babajanov T.L., Abidov N., Akramkhodjaev A.M., Avazkhodjaev Kh.Kh., Labutina L.I., Tolstov S.P., Galkin L.L., Samashev Z.S., and others. Their works have significantly advanced the understanding of the oil and gas potential of the Morckoe field; however, for a final justification of prospective zones, further study of deep structures, development of new geological and geophysical analysis methods, and the application of advanced exploration drilling technologies are required.

Modern oil and gas production is associated with the development of hard-to-recover reserves and the exploitation of areas with high geological and technical complexity, including the Morckoe field and the Ogayskoye block. Such objects are characterized by unstable formations, high formation pressure gradients, and the presence of water-bearing and clay-rich intervals prone to swelling and collapse, which significantly complicate the drilling process.

Under these conditions, requirements for the quality and stability of drilling fluid increase, as it ensures borehole wall stability, cuttings transport, and pressure control. Deviations in its density lead to losses, stuck pipe incidents, and borehole collapse. Meanwhile, in most drilling operations, density control is performed periodically and manually, which does not allow timely response to changes in the wellbore.

This necessitates a transition to continuous automated density monitoring with real-time data analysis capabilities. The development and implementation of a real-time measurement system align with the goals of drilling digitalization, improve safety, reduce operational risks, and ensure adaptive process control. The implementation of such a system at the Morckoe field and the Ogayskoye block is a technically and economically feasible solution for improving the efficiency and reliability of drilling operations.

Purpose and objectives of the research. The aim of the dissertation is to improve the efficiency of drilling and well completion in complex geological conditions through the implementation of a system for real-time automatic measurement of drilling fluid density, ensuring:

- timely and accurate control of drilling fluid density;
- prompt decision-making for adjusting the formulation and treatment technology of the drilling fluid;
- reduction of the risk of complications and abnormal situations during drilling operations;
- reduction of drilling and well completion time;
- ensuring the safety of production processes and wellbore stability.

Research objectives:

1. To analyze the geological, physical, and lithological characteristics of the productive section based on core studies and geophysical data interpretation in order to identify features affecting drilling fluid selection and parameters.

2. To study modern methods of drilling fluid density control, identify their limitations under unstable formation conditions, and justify the feasibility of implementing automated density monitoring systems.

3. To investigate the influence of drilling fluid density on wellbore stability and drilling performance parameters under geotechnical complications.

4. To develop a structural-functional model of an automated drilling fluid density measurement system adapted to the conditions of the studied field.

5. To conduct laboratory and pilot-scale industrial tests of the system and determine its accuracy, stability, and reliability under different drilling regimes.

6. To evaluate the technical and economic efficiency of the automated system compared to conventional monitoring methods in the specific field conditions.

7. To develop methodological recommendations for implementing automated drilling fluid density monitoring systems at fields with similar geological and technical characteristics.

Object of the research – the processes of drilling and well completion at the Morckoe field, including the Ogayskoye block, and the functioning of the drilling fluid circulation system under complex geological and technical conditions.

Subject of the research – drilling fluid density, methods of its measurement and real-time monitoring, as well as its influence on wellbore stability and overall drilling efficiency.

Research methods – the study employed a set of methods aimed at improving drilling efficiency in complex geological conditions through the implementation of an automated real-time drilling fluid density control system.

Geological and analytical studies included core analysis, well logging (GIS) data interpretation, and structural-lithological characterization of productive formations using petrographic analysis and interpretation of well logging data to evaluate porosity, permeability, and clay content of rocks. Laboratory investigations of drilling fluid covered the determination of its density, viscosity, pH, and other physicochemical parameters in accordance with ISO/GOST and API standards, with a comparison of manual and automated measurements.

To assess the effect of drilling fluid density on wellbore stability, mathematical modeling methods were applied, including rock failure mechanics models and hydraulic calculations. The integrated approach made it possible to obtain scientifically substantiated results and develop an effective real-time monitoring system for drilling fluid properties.

Scientific statements submitted for defense:

1. The filtration properties of rocks in the Morckoe field and the Ogayskoye block depend on lithofacies composition and the degree of fracturing and secondary porosity development, where certain intervals are characterized by increased permeability at moderate porosity. This leads to high sensitivity of the formation to changes in hydrostatic pressure and,

consequently, requires continuous operational monitoring of drilling fluid density to ensure wellbore stability and safe drilling operations.

2. The displacement of a magnetic core caused by changes in drilling fluid density leads to a monotonic increase in coil inductance with increasing density due to an increase in the effective magnetic permeability of the magnetic circuit.

3. Under hydrostatic interaction between the magnetic core and drilling fluid, the position of the core within the measuring coil is uniquely determined by the density of the medium, which forms the physical basis for using a magnetic field to measure the density of drilling fluids.

Scientific novelty of the work:

1. A comprehensive inductive density measurement model was developed, combining electromagnetic coil modeling and hydrodynamic description of real drilling fluid flow in the measurement channel.

2. Analytical relationships between inductance variation and fluid density were obtained for typical drilling fluid parameters, demonstrating the applicability of the inductive principle for direct field density measurements.

3. Hydraulic regimes of non-Newtonian drilling fluids were calculated, and their influence on the spatial velocity distribution in the measuring channel and on the accuracy of inductive sensor signal conversion was evaluated.

Justification of the novelty and significance of the obtained results:

The novelty and significance of the obtained results are confirmed by a patent for an invention of the Republic of Kazakhstan for an automated drilling fluid density measurement system, which enables real-time density measurement without direct operator involvement.

Practical significance of the work:The results of the research can be applied in the activities of public and private organizations engaged in drilling operations, as well as in scientific and design institutions dealing with well drilling and well completion. The implementation of automated drilling fluid density control allows for a reduction in accident rates, minimization of drilling complications (stuck pipe incidents, lost circulation, and wellbore collapse), as well as a decrease in downtime and overall well construction time.

Relation to program-based scientific research:The dissertation was carried out in close connection with program-based scientific research implemented within the framework of state and industry programs for the development of the oil and gas sector, aimed at digitalization and improving the efficiency of drilling technological processes.

The development of an automated drilling fluid density monitoring system corresponds to the priority directions of national scientific and technical policy in the field of digital technologies and production process automation, as reflected in programs such as the “Digital Oil and Gas 2030” digital transformation program, the State Program for the Development of Science and Technology in the Field of Hydrocarbon Exploration and Production, and industry projects aimed at improving the safety and environmental sustainability of drilling operations.

Within these programs, special attention is given to the development of intelligent control systems for technological processes, including continuous monitoring and analysis of drilling fluid density, which ensures improved reliability and safety of drilling operations.

The results of the work are integrated with existing digital platforms and production management systems, ensuring their practical applicability and compliance with modern trends in scientific and technological development in the industry.

Thus, the dissertation contributes to the implementation of key tasks of program-based scientific research aimed at the digital modernization of the oil and gas complex and enhancing its competitiveness.

Personal contribution of the author:

The author defined the aim and objectives of the research and developed the scientific concept of the work based on the analysis of the physical and lithological characteristics of the field and modern methods of drilling fluid control.

The author independently developed a structural-functional model of an automated real-time drilling fluid density measurement system, including the selection and justification of sensor composition, the architecture of the hardware-software complex, and data processing algorithms.

The author conducted all main experimental investigations, including laboratory tests and pilot industrial trials of the system at drilling sites, analyzed the obtained data, and evaluated the effectiveness of the developed system.

The author independently performed the analysis of the implementation results and prepared all main sections of the dissertation, including theoretical and practical parts, as well as prepared publications related to the research topic.

Thus, all key scientific, research, and experimental work presented in the dissertation was carried out personally by the author.

Reliability of the obtained results: The reliability of the dissertation results is ensured by the use of modern research methods, certified equipment, and high-precision measuring instruments. Laboratory and pilot industrial tests were carried out in accordance with current standards in the field of drilling and drilling fluid investigation, and the obtained data were repeatedly reproduced under various conditions, which minimizes the likelihood of random and systematic errors.

Data processing was performed using modern mathematical and statistical methods that ensure the objectivity of the conclusions. The scientific novelty and practical significance are confirmed by expert reviews and the implementation of the developed system into industrial practice.

Thus, the presented materials and conclusions of the dissertation are reliable and can be used for further research and practical applications in the field of well drilling.

Approbation of research results and publications:

In the period from April 28 to May 28, 2025, a scientific internship was completed at Tashkent State Technical University named after Islam Karimov.

The main results of the research were presented at an extended meeting of the Department of “Geology and Petrochemical Engineering.”

The main provisions of the dissertation were published in 8 scientific works, including: 2 articles in journals indexed in Scopus and Clarivate Analytics databases; 3 articles in journals recommended by the Committee for Quality Assurance in Science and Higher Education; 1 article in another international scientific journal; and 2 articles in proceedings of international scientific and practical conferences.

Within the framework of the dissertation tasks, a patent for the invention “System for Automatic Measurement of Drilling Fluid Density” was obtained from the National Institute of Intellectual Property of the Republic of Kazakhstan.

Scope and structure of the work:

The dissertation consists of an introduction, four chapters, a conclusion, a list of references, and appendices.

The total volume of the work is 143 pages of typewritten text (subject to final formatting), including 40 figures, 20 tables, and 11 appendices. The list of references includes 93 sources.

Factual basis: The factual basis of the dissertation research is based on the author’s research materials, published articles and monographs in domestic and international publications, as well as archival reports related to the dissertation topic.

The dissertation was completed at the Department of “Geology and Petrochemical Engineering” of the Sh. Yessenov Caspian University of Technology and Engineering.