# ABSTRACT

of the dissertation for the degree of Doctor of Philosophy (Ph.D.)
in the educational program 8D07202 – *"Petroleum Engineering"*

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## IMPROVEMENT OF WATER-BASED DRILLING FLUIDS USING NANOPARTICLES AND MODIFIED POLYMERS TO ENHANCE SHALE STABILITY

**Relevance of the topic:**

The modern oil and gas industry is facing increasingly complex geological conditions, among which clay formations present particular challenges due to their high tendency to swell and disintegrate upon contact with aqueous media. During drilling operations through such formations, complications often arise, including wellbore instability, drilling fluid loss, increased filtration, and, consequently, higher time and financial costs. Under these circumstances, the development of effective water-based drilling fluids capable of ensuring the thermochemical stability of wellbore walls when penetrating clay and shale formations becomes especially important. The use of environmentally friendly water-based systems is preferable in terms of sustainable development and environmental regulations; however, such fluids are the most vulnerable to interaction with hydrophilic minerals. One of the most promising approaches to solving this problem is the application of modified polymers and nanomaterials, which can simultaneously perform several functions: inhibit the swelling of clay minerals, reduce rock permeability by forming a dense filter cake, and improve the rheological and filtration properties of the drilling fluid.
Modified polymers can create protective films on the rock surface and alter its wettability, while nanoparticles, due to their small size and large surface area, effectively seal micropores and minimize fluid invasion. The relevance of this research is determined by the need to develop and implement an integrated approach that includes the synthesis and selection of effective polymer–nanocomposite additives tailored to the conditions of specific formations. This direction opens up opportunities to improve the technological reliability of drilling fluids, reduce costs, minimize accident risks, and enhance wellbore stability when drilling in complex geological environments.

**Research Objective:**

The objective of this research is the development and justification of an effective formulation of a water-based drilling fluid, modified with polymeric and nanocomposite additives (in particular, graphene oxide and nanocellulose), which ensures improved wellbore wall stability in clay formations and reduces filtration losses during drilling.

**Research Tasks:**

To achieve this objective, the following tasks were addressed in the course of the study:

1. Analysis of literature sources on the interaction of water-based drilling fluids with clay formations and modern methods of swelling inhibition.
2. Synthesis and characterization of a graphene oxide–nanocellulose (GO/NC) nanocomposite, including the study of its structure, dispersibility, and stability in aqueous media.
3. Modification of a polymer additive to enhance its hydrophobic and inhibiting properties with respect to clay minerals.
4. Development of a drilling fluid formulation containing GO/NC and a modified polymer, with evaluation of its rheological and filtration properties.
5. Experimental investigation of the effect of the obtained fluid on filtration properties, filter cake thickness, and the stability of clay samples.
6. Assessment of changes in the contact angle of shale surfaces treated with the new fluid to confirm the improvement of their hydrophobicity.
7. Comparative analysis of the obtained results with the characteristics of traditional drilling fluids used for drilling in clay formations.

**Research Methods:**

The choice of research methodology is justified, and the methodology itself is described in detail in the dissertation. The results were obtained using modern scientific research methods, including up-to-date techniques for data processing and interpretation with the use of computer technologies. Theoretical conclusions, proposed models, and identified relationships and patterns are confirmed by experimental studies, which ensures the reliability of the obtained results. The methods applied include IR spectroscopy, rheological testing, electron microscopy, and clay swelling tests using the OFITE apparatus.

**Scientific Novelty of the Research:**

1. A new formulation of a water-based drilling fluid has been proposed and substantiated. It contains a modified hydrophobic polymer and a graphene oxide–nanocellulose (GO/NC) nanocomposite, which provides enhanced inhibiting properties against clay formations and reduces filtration losses.
2. An approach to the integrated use of nanomaterials and polymers has been developed, achieving a synergistic effect: GO/NC nanoparticles form a dense filter cake and reduce rock permeability, while the modified polymer adsorbs onto the clay surface, stabilizing its structure and altering wettability.
3. For the first time, the effect of the GO/NC composite on contact angles and filtration properties of water-based drilling fluids has been experimentally evaluated, enabling quantitative confirmation of improved shale hydrophobicity when treated with the new fluid.
4. The possibility of controlling the structure and thickness of the filter cake through the optimal ratio of nanoparticles and polymer additives has been demonstrated, contributing to improved wellbore wall stability and reduced invasion of drilling fluid into the formation.
5. The patterns of influence of the developed additives on the rheological and filtration properties of the drilling fluid have been established, allowing for targeted formulation adjustments depending on the properties of a specific geological section.

**Theoretical and Practical Significance of the Research:**

The dissertation possesses both theoretical and practical significance. The theoretical contributions expand scientific understanding in the field of drilling fluid development and clay formation stability, while the obtained results may serve as a foundation for further studies in this area. The practical value lies in the possibility of applying the proposed solutions during the drilling and operation of wells under challenging conditions. All practical recommendations are novel, applied in nature, and may be implemented in the industry to increase the efficiency and reliability of drilling operations.

**Provisions Submitted for Defense:**

1. A scientifically substantiated formulation of a water-based drilling fluid modified with a graphene oxide–nanocellulose (GO/NC) nanocomposite and a hydrophobic polymer, ensuring reduced filtration losses and improved wellbore wall stability in clay deposits.
2. Experimentally confirmed influence of GO/NC on the filtration properties of the fluid: reduction of filtrate volume under low and high pressure, and decrease in filter cake thickness.
3. Proven change in wettability of clay surfaces when treated with a GO/NC-containing fluid, achieved through an increase in contact angle and formation of a hydrophobic layer.
4. Established patterns of influence of the modified additives on the rheological characteristics of the drilling fluid and its stability conditions during drilling through clay and shale intervals.
5. A methodology for evaluating the effectiveness of polymer–nanocomposite additives based on a set of parameters: filtration, wettability, filter cake thickness, and structural–mechanical properties of the fluid.

**Compliance of the Dissertation with Priority Areas of Science Development and State Programs:**

The dissertation corresponds to priority areas of scientific development and is aimed at improving water-based drilling fluids through the use of nanoparticles and modified polymers to enhance the stability of clay formations. The results, conclusions, and recommendations obtained during the research have practical significance and may be useful for further improvement of well drilling technologies under challenging conditions, for the development of new drilling fluid formulations, as well as for use in scientific research and educational activities.

**Author's Personal Contribution, Publications, and Validation of Practical Results:**

In this research work, the author adheres to the principle of independence and applies a comprehensive scientific approach to solving the assigned tasks. The author independently developed the research methodology, selected drilling fluid formulations, conducted laboratory experiments, and performed processing and analysis of the obtained results. Laboratory data were obtained during systematically organized experiments in compliance with GOST and API standards. All conclusions and recommendations are based on the author's own experimental data and scientific interpretation.

**Approbation of the Work:**

The materials of the dissertation research were presented and discussed at two international scientific conferences:

1. *International Conference on Polymers, Composites, Nanocomposites and Biocomposites – 2023*, held at Satbayev University (Almaty, Kazakhstan) from December 11 to 13, 2023.
2. *International Conference on Nano Structured Materials and Nanocomposites*, held at Mahatma Gandhi University (Kottayam, Kerala, India) from May 10 to 12, 2024.

**Publications:**

The main results obtained during the dissertation research have been published in three scientific articles included in the Scopus database. Of these, two articles were published in international journals ranked in Q2 quartile:

1. *A Comprehensive Review of Carbon Nanomaterials in the Drilling Industry*, Y.K. Ospanov, G.A. Kudaikulova, DOI: 10.1002/pol.20240220.
2. *Improving Shale Stability through the Utilization of Graphene Nanopowder and Modified Polymer-Based Silica Nanocomposite in Water-Based Drilling Fluid*, Yerlan Kanatovich Ospanov*, Gulzhan Abdullaevna Kudaikulova, Murat Smanovich Moldabekov, Moldir Zhumabaevna Zhaksylykova, DOI: 10.3390/pr12081676.

And one article was published in a Q1 quartile journal:

1. *Synergistic Effects of Graphene Oxide and Nanocellulose on Water-Based Drilling Fluids: Improved Filtration and Shale Stabilization*, Yerlan Kanatovich Ospanov*, Gulzhan Abdullaevna Kudaikulova, DOI: 10.3390/polym17070949.

**Structure and Volume of the Dissertation:**

The dissertation includes normative references, a list of symbols and abbreviations, an introduction, four chapters, a conclusion, and a list of references.

The total volume of the dissertation is 100 pages, including 8 tables and 29 figures. The list of references contains 148 sources.

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