ABSTRACT

of the dissertation for the degree of Doctor of Philosophy (PhD) in the educational program 8D07107 – «Chemical Engineering of Hydrocarbon»

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INVESTIGATION OF THE PROCESSES OF PARAFFIN DEPOSITION AND DEVELOPMENT OF METHODS TO IMPROVE RHEOLOGICAL PARAMETERS OF HIGHLY WAXY OIL

Relevance of the Research Topic:

One of the pressing challenges in Kazakhstan's oil industry is the transportation of crude oils with high contents of paraffins and resins, particularly from the Mangyshlak fields, Kumkol group, and the resinous oils of the Buzachi Peninsula. These crude oils are characterized by high pour points, abnormal viscosity, elevated shear stress, and a strong tendency to form asphalt-resin-paraffin deposits (ARPD) on the internal surfaces of pipelines.

Such factors severely complicate transportation, increase energy consumption, and lead to additional operational costs. Therefore, improving the low-temperature properties of crude oil—such as flowability and mobility—and preventing ARPD formation are crucial for ensuring the efficiency of oil transport infrastructure.

Current approaches to reducing transportation costs of high-paraffin oils include the adjustment of the crude blend composition produced in western Kazakhstan. Optimizing the blend ratio, particularly by increasing the fraction of light Aktobe crude, has been shown to significantly improve rheological and physicochemical properties, reduce viscosity, and enhance flowability. This also alters the fractional and component composition of the crude oil—such as paraffin, asphaltene, and resin contents—ultimately restructuring the dispersion system.

Such structural changes in the dispersion medium make crude oils more receptive to thermal and depressant treatment, thereby preventing paraffin deposition and reducing energy costs during transport.

Thus, investigating the mechanisms of paraffin deposition and developing methods to improve the viscosity of high-paraffin crude oils is not only a relevant scientific problem but also of significant practical importance. The results of this study could lead to the development of effective oil transportation technologies, reducing operational costs and enhancing the profitability of oil production and pipeline operations in Kazakhstan. This substantiates the importance and timeliness of the proposed research within the framework of the dissertation work.

Research Objective: To develop scientifically grounded methods for preventing paraffin deposition and enhancing the efficiency of high-paraffin crude oil transportation by studying their physicochemical properties, optimizing thermal treatment processes, and implementing innovative chemical reagents to improve rheological characteristics and minimize operational expenses.

Research Tasks:

1. To study the main properties of high-paraffin crude oil and its paraffin deposition processes;
2. To develop methods for improving rheological parameters and investigate the effect of thermal treatment and crude composition on paraffin deposition;
3. To synthesize a depressant additive and assess the efficiency of the developed reagents in inhibiting and dispersing ARPD for optimizing oil transport conditions.

Research Objects: Crude oils from the Kumkol, Akshabulak, Aktobe fields, and Western Kazakhstan oil mixtures (WKOM).

Research Methods: Experimental investigations were conducted using high-precision modern equipment (accuracy class 0.3–1.0). All analytical methods complied with GOST standards, and results were validated through triplicate experiments. Techniques employed included infrared (IR) spectroscopy, rheological measurements, electron microscopy, and chromatographic analysis.

Scientific Novelty: This research introduces and systematically analyzes novel approaches to combating paraffin deposition, based on an in-depth evaluation of crude oil physicochemical characteristics, paraffin crystallization mechanisms, and the integrated application of innovative technologies. A new depressant reagent, designated PTE, was synthesized for the first time and demonstrated high efficiency in inhibiting paraffin formation. The addition of PTE to crude oil reduced viscosity and minimized ARPD formation, offering promising prospects for improving the transportability of heavy crude oils.

Theoretical and Practical Significance: The theoretical significance lies in the development of fundamentally new approaches for analyzing, predicting, and mitigating paraffin deposition in high-paraffin crude oils. A comprehensive study of paraffin crystallization mechanisms, coupled with the development of innovative chemical and physical suppression methods, contributes to the advancement of fundamental knowledge and provides effective technological solutions for the petroleum industry. The mechanism of action of the synthesized PTE reagent has been elucidated, particularly regarding its effects on wax crystal morphology, distribution, and structure.

Key Points for Defense:

1. The initial physicochemical properties of crude oils and the nature of normal alkanes present in their composition were studied. Their influence on the aggregation stability of the oil dispersion system was established. The identified patterns enabled the development of optimal conditions for transporting high-paraffin crude oils, contributing to viscosity reduction and paraffin prevention, thereby minimizing energy expenditures in pipeline transport.
2. It was found that thermal treatment significantly influences the rheological behavior of crude oil mixtures. For the Kumkol-Akshabulak oil mixtures (KAOM), optimal heating at 60°C resulted in a substantial viscosity decrease. For the WKOM, thermal treatment at 90°C preserved Newtonian flow behavior down to 10°C. The improved rheological properties persisted for up to five days before

gradual viscosity increase. These findings provide a basis for recommending optimal thermal parameters to enhance transport efficiency of paraffin-rich crude oils. Additionally, increasing the concentration of Aktobe crude oil in WKOM (20% and above) enhances its thermal treatability at 60°C.

3. The combined application of thermal treatment and the synthesized PTE depressant significantly improves the rheological properties of high-paraffin crude oils. The maximum pour point depression for WKOM was achieved at 90°C and 1000 ppm PTE, with a 15°C reduction in pour point. For KAOM, the reduction was 9°C. PTE at 500 ppm at 90°C for both WKOM and KAOM exhibited sustained inhibitory effects, maintaining viscosity, shear stress, and pour point at optimal levels for 10 days, confirming the long-term effectiveness and reliability of the reagent in improving flowability and minimizing paraffin formation.

Compliance with Scientific Development Directions and Government Programs: The dissertation was carried out within the framework of program-targeted funding from the Ministry of Science and Higher Education of the Republic of Kazakhstan for 2024–2026 under project BR24992868 “Development of Innovative Technology and Software Products for the Use of Multicomponent Alloys to Increase the Productivity of Heavy Oil Wells”, Contract No. 375-PCF 24-26 dated October 1, 2024.

Author's Personal Contribution, Publications, and Validation of Practical Results: The author’s contribution includes literature analysis and critical evaluation, execution of experimental studies, application of physicochemical analysis methods, interpretation and systematization of the obtained results, and formulation of scientific conclusions.

Validation of the Work: The findings of the dissertation were presented and discussed at the VI International Scientific and Practical Conference “Prospects for Innovative Development of Chemical Technology and Engineering”, dedicated to the 100th anniversary of Professor Boris Konstantinovich Marushkin (Marushkin Readings VI), held in a hybrid format at Ufa State Petroleum Technological University (November 17–19, 2021, Ufa, Russian Federation). The materials have also been submitted for presentation at the “4th Global Summit on Advances in Earth Science and Climate Change” (Adv. ESCC 2025), to be held September 29–30, 2025, in Berlin, Germany.

Publications:

The main results of the dissertation have been published in three scientific papers: two in international journals indexed in Scopus with a percentile of 60, and one with a percentile of 76. Additionally, two publications appeared in proceedings of international scientific conferences.

Structure and Volume of the Dissertation:

The dissertation includes normative references, a list of abbreviations and terms, an introduction, three chapters, a conclusion, and a list of references. The total volume is 107 pages, including 19 tables and 62 figures. The reference list contains 134 sources.