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MODERN CHEMICAL DEPRESSOR ADDITIVES FOR REDUCING THE POUR POINT OF PARAFFINIC OILS

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It was established that the application of modern chemical pour point depressant additives makes it possible to reduce the pour point temperature of paraffinic crude oils by 10–30 °C and decrease oil viscosity by 40–56%. It was shown that polymeric and composite depressant reagents based on ethylene-vinyl acetate copolymers, polyolefins, and surfactants demonstrate the highest efficiency. The introduction of depressant additives was found to inhibit the aggregation of paraffin crystals, reduce the intensity of asphaltene-resin-paraffin deposit formation, and improve oil flowability at low temperatures.

It was also determined that the use of modern depressant compositions contributes to improving oil transportation efficiency, reducing hydraulic resistance, and increasing the operational reliability of pipeline systems.

The practical significance of the study lies in the possibility of applying the obtained results for selecting effective reagents for the treatment and transportation of high-paraffin crude oils.

KEYWORDS. *depressants, oil, paraffin, emulsion, viscosity, crystallization, temperature, rheology, sediments, transportation.*

СОВРЕМЕННЫЕ ХИМИЧЕСКИЕ ДЕПРЕССОРНЫЕ ПРИСАДКИ ДЛЯ СНИЖЕНИЯ ТЕМПЕРАТУРЫ ЗАСТЫВАНИЯ ПАРАФИНИСТЫХ НЕФТЕЙ

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ЗАПАДНО-КАЗАХСТАНСКИЙ АГРАРНО-ТЕХНИЧЕСКИЙ УНИВЕРСИТЕТ ИМ. ЖАНГИР ХАНА
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Установлено, что применение современных химических депрессорных присадок позволяет снизить температуру застывания парафинистых нефтей на 10–30 °С и уменьшить вязкость нефти на 40–56 %. Показано, что наибольшую эффективность демонстрируют полимерные и композиционные депрессорные реагенты на основе этиленвинилацетатных сополимеров, полиолефинов и поверхностно-активных веществ. Выявлено, что введение депрессорных присадок препятствует агрегации парафиновых кристаллов, снижает интенсивность образования асфальтосмолопарафиновых отложений и улучшает текучесть нефти при низких температурах.

Установлено, что применение современных депрессорных композиций способствует повышению эффективности транспортировки нефти, снижению гидравлического сопротивления и повышению надежности эксплуатации трубопроводных систем.

Практическая значимость работы заключается в возможности использования результатов исследования при выборе эффективных реагентов для подготовки и транспортировки высокопарафинистых нефтей.

КЛЮЧЕВЫЕ СЛОВА: *депрессоры, нефть, парафин, эмульсия, вязкость, кристаллизация, температура, реология, отложения, транспортировка.*

ПАРАФИНДІ МҰНАЙДЫҢ ҚАТАЮ ТЕМПЕРАТУРАСЫН ТӨМЕНДЕТУГЕ АРНАЛҒАН ЗАМАНАУИ ХИМИЯЛЫҚ ДЕПРЕССОРЛЫҚ ҚОСПАЛАР

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ЖӘҢГІР ХАН АТЫНДАҒЫ БАТЫС ҚАЗАҚСТАН АГРАРЛЫҚ-ТЕХНИКАЛЫҚ УНИВЕРСИТЕТІ
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Қазіргі заманғы химиялық депрессорлық қоспаларды қолдану парафинді мұнайлардың қату температурасын 10–30 °С-қа төмендетуге және мұнай тұтқырлығын 40–56 %-ға азайтуға мүмкіндік беретіні анықталды. Этиленвинилацетат сополимерлері, полиолефиндер және беттік-белсенді заттар негізіндегі полимерлік және композициялық депрессорлық реагенттердің ең жоғары тиімділік көрсететіні дәлелденді. Депрессорлық қоспаларды енгізу парафин кристалдарының агрегациясын тежеп, асфальт-шайыр-парафин шөгінділерінің түзілу қарқындылығын төмендететіні және төмен температура жағдайында мұнайдың аққыштығын жақсартатыны анықталды.

Заманауи депрессорлық композицияларды қолдану мұнай тасымалдау тиімділігін арттыруға, гидравликалық кедергіні азайтуға және құбыр жүйелерінің пайдалану сенімділігін жоғарылатуға ықпал ететіні көрсетілді.

Зерттеу нәтижелерінің практикалық маңыздылығы жоғары парафинді мұнайларды дайындау мен тасымалдауға арналған тиімді реагенттерді таңдауда қолдану мүмкіндігімен сипатталады.

ТҮЙІН СӨЗДЕР: *депрессорлар, мұнай, парафин, эмульсия, тұтқырлық, кристалдану, температура, реология, шөгінділер, тасымалдау*

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Introduction. In recent years, there has been a steady increase in the production of paraffinic crude oils with a high content of solid hydrocarbons, which significantly complicates the processes of oil production, transportation, and refining. The main problem associated with the use of such oils is the increase in pour point temperature and the formation of asphaltene-resin-paraffin deposits (ARPD), which leads to an increase in oil viscosity, a decrease in pipeline throughput, and higher energy consumption during transportation [1].

Paraffinic hydrocarbons consist mainly of a mixture of solid alkanes with carbon chain lengths ranging from C16 to C40, which crystallize at lower temperatures and form a spatial network structure. The formation of paraffin gel causes a sharp deterioration in the flow properties of oil and, in some cases, may completely stop the transportation of the product through pipelines. In addition, the composition and properties of paraffin deposits vary significantly depending on the chemical composition of the oil and its operating conditions [2].

Traditional methods for combating high pour point temperatures include thermal treatment, dilution of oil with low-viscosity hydrocarbons, and deparaffinization processes. However, these methods are characterized by high energy consumption and high operating costs. In this regard, the use of chemical reagents — pour point depressant additives — has become particularly important, since they make it possible to effectively regulate the low-temperature properties of oil without significant technological costs [3].

Pour point depressants are high-molecular organic compounds capable of modifying the crystallization process of paraffins and preventing the formation of a strong crystalline structure. Their mechanism of action is based on the adsorption of additive molecules on the surface of growing paraffin crystals, which leads to the formation of defects in the crystal lattice and a decrease in the oil pour point. The use of such additives significantly improves the rheological properties of oil and reduces the likelihood of paraffin deposit formation[4].

Modern studies demonstrate that polymeric pour point depressants, such as ethylene-vinyl acetate copolymers, alkyl (meth)acrylates, and polyolefin compounds, exhibit the highest efficiency. These substances interact with n-paraffins, modify their morphology, and reduce crystal size, thereby improving the flowability of oil at low temperatures [5].

In recent years, technologies for producing composite pour point depressants based on by-products of vegetable oil processing, including cotton gudrons and soapstocks, have been actively developing. The use of such raw materials makes it possible to reduce the cost of reagents and increase their efficiency due to the synergistic effect of the components in the composition.

Thus, the development and application of modern chemical pour point depressants represent one of the most promising approaches for improving the efficiency of production

and transportation of paraffinic crude oils. A review of modern types of pour point depressants, their mechanisms of action, and the factors affecting their efficiency is of significant scientific and practical importance.

Materials and methods

Modern scientific publications focused on the development and application of chemical pour point depressants aimed at reducing the pour point temperature of paraffinic crude oils and preventing the formation of asphaltene-resin-paraffin deposits (ARPD) were used as materials for the review study [6,7].

Scientific articles, dissertation studies, and experimental works examining the composition, properties, and mechanisms of action of pour point depressants with different chemical natures were used as information sources [8]. Particular attention was paid to studies investigating the influence of depressant reagents on the rheological and low-temperature properties of crude oils, including pour point temperature, viscosity, and the tendency to form paraffin deposits [9].

The analyzed materials included studies devoted to the development of composite pour point depressants based on surfactants, polymer compounds, and solvents, as well as investigations evaluating their effectiveness at different concentrations [6]. It was found that the addition of depressant compositions in concentrations of 0.02–0.04 wt.% can reduce the oil pour point from positive to negative temperatures, while the oil viscosity decreases by 40–56%, demonstrating the high efficiency of chemical reagents [10].

In addition, materials related to the study of the effect of pour point depressants on preventing the formation of asphaltene-resin-paraffin deposits were also used. Research results showed that the application of chemical reagents reduces the amount of paraffin deposits and improves oil flowability at low temperatures, significantly increasing the efficiency of oil production and transportation processes [11, 13].

The following methods of scientific analysis were applied during the review study.

Analytical method

The main research method was an analytical review of scientific literature, including the systematization and generalization of data on the composition and properties of modern pour point depressants. The results of experimental studies investigating the effect of various chemical reagents on the oil pour point and its rheological characteristics were analyzed.

Within the framework of the analytical approach, the dependence of depressant efficiency on their chemical structure, concentration, oil composition, and operating conditions was considered. In addition, the mechanisms of interaction between additives and paraffin crystals, as well as the features of their influence on paraffin crystallization processes, were analyzed.

Comparative Analysis Method

To evaluate the effectiveness of different types of pour point depressants, a comparative analysis of experimental data presented in scientific publications was carried out. Indicators such as reduction in pour point temperature, changes in oil viscosity, and decrease in the amount of paraffin deposits resulting from the use of various reagents were compared.

As a result of the comparative analysis, the most effective classes of pour point depressants were identified, and the main factors affecting their efficiency were determined.

Methods for Evaluating Low-Temperature Properties of Oil

During the analysis of literature data, information obtained using standard methods for determining the low-temperature characteristics of crude oil was taken into account, including:

– determination of oil pour point temperature;

– determination of dynamic viscosity of oil;

– investigation of paraffin crystal formation processes;

– determination of asphaltene-resin-paraffin deposit (ARPD) content using the "cold finger" method;

– analysis of changes in the structure of paraffin crystals under the influence of pour point depressants.

The application of these methods makes it possible to objectively evaluate the effectiveness of pour point depressants and their influence on the technological properties of oil under low-temperature conditions.

Method of Scientific Data Systematization

At the final stage of the study, the obtained data were systematized in order to identify the main development trends of modern pour point depressant technologies. The main groups of pour point depressants, their chemical characteristics, and application areas were identified.

The systematization results made it possible to form generalized concepts regarding the mechanisms of action of modern pour point depressants and to determine the prospects for their further development [12, 13].

Results and discussion

Classification of Modern Chemical Pour Point Depressants Analysis of modern scientific studies has shown that chemical pour point depressants are among the most effective means for regulating the low-temperature properties of paraffinic crude oils. Depending on their chemical nature and mechanism of action, pour point depressants are divided into several main groups[13].

Table 1 demonstrates the classification of modern pour point depressants according to their chemical composition, properties, and application areas. The analysis shows that polymeric and composite additives exhibit the highest efficiency in improving the rheological properties of paraffinic crude oils and reducing their pour point temperature.

Table 1 – **Classification of Modern Pour Point Depressants**

Additive Type	Chemical Basis	Main Properties	Application Area
Polymeric	Ethylene-vinyl acetate copolymers (EVA)	Reduction of pour point temperature	Paraffinic crude oils
Alkyl (meth)acrylates	Polymers of acrylic acid esters	Improvement of flowability	High-viscosity oils
Polyolefins	Polypropylene, polyethylene	Reduction of viscosity	Pipeline transportation
Composite	Polymer + surfactants (surfactants) + solvents	Complex action	Heavy crude oils
Ester-based	Complex esters of fatty acids	Modification of paraffin crystals	Diesel fractions

The most widely used are polymeric pour point depressants, among which ethylene-vinyl acetate copolymers (EVA), alkyl methacrylates, and polyolefin compounds occupy a special place [7]. These compounds are capable of interacting with paraffin crystals and modifying their morphology, thereby preventing the formation of a dense crystalline structure. As a result, the oil pour point decreases and its flowability at low temperatures improves.

According to the results of conducted studies, composite pour point depressants consisting of polymer components, surfactants, and solvents demonstrate the highest efficiency. Such compositions exert a complex effect on the paraffin crystallization process and prevent the formation of asphaltene-resin-paraffin deposits [14].

Mechanism of Action of Pour Point Depressants

Analysis of literature data showed that the effectiveness of pour point depressants is associated with their ability to modify the paraffin crystallization process. The main mechanism of action is based on the adsorption of additive molecules onto the surface of forming paraffin crystals. This leads to the formation of defects in the crystal structure and reduces the ability of crystals to aggregate [15].

As the temperature decreases, paraffinic hydrocarbons begin to form a spatial network structure, which causes an increase in oil viscosity and a rise in the pour point temperature. The introduction of pour point depressants reduces the size of paraffin crystals and prevents their agglomeration into large aggregates. As a result, the strength of the paraffin framework decreases and the flowability of the oil improves.

Figure 1 illustrates the mechanism of action of depressant additives. The additives adsorb on the surface of paraffin crystals, disrupt their growth and aggregation, and

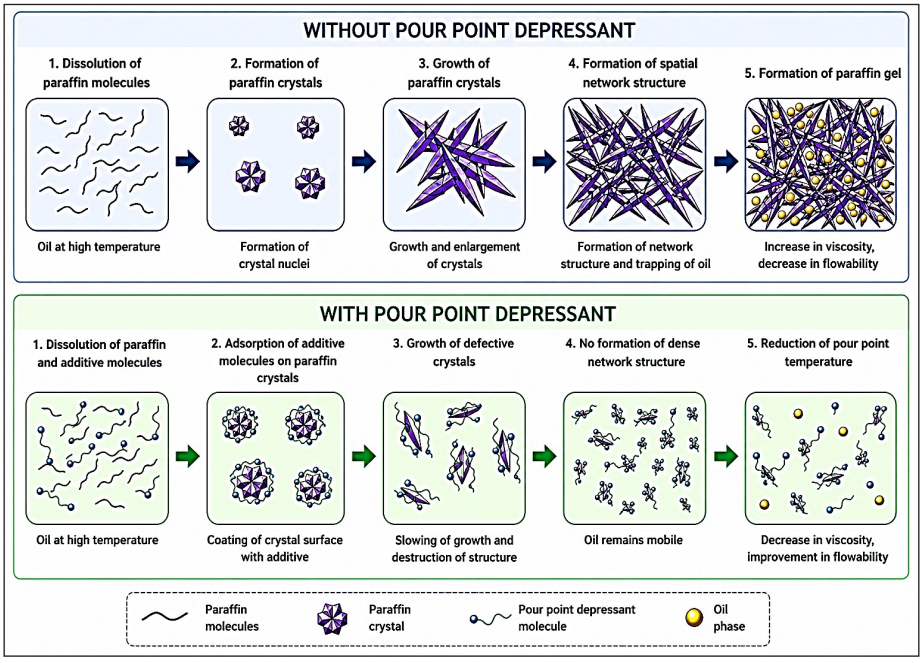

Figure 1 – **Diagram of the mechanism of action of depressant additives**

prevent the formation of a dense crystalline network structure. As a result, oil flowability improves and the intensity of paraffin deposit formation decreases.

Studies have shown that when depressant compositions are added at concentrations of 0.02-0.04 wt.%, the oil pour point can decrease from +31 °C to negative values, reaching a range from –3 to +4 °C. In addition, oil viscosity decreases by 40–56%, which confirms the high efficiency of depressant reagents.

Influence of Oil Chemical Composition on the Efficiency of Pour Point Depressants

The analysis results demonstrated that the effectiveness of pour point depressants largely depends on the chemical composition of crude oil, particularly on the content of paraffins, resins, and asphaltenes. Each crude oil is characterized by a specific composition of asphaltene-resin-paraffin deposits; therefore, the selection of additives should take into account the characteristics of the oil system[16].

It was established that an increase in the content of high-molecular-weight paraffins leads to an increase in the oil pour point and complicates the transportation process. Under such conditions, the use of pour point depressants significantly reduces the intensity of paraffin deposit formation and improves the rheological properties of oil.

Some studies have shown that the application of pour point depressants contributes to a decrease in the amount of formed paraffin deposits, which is associated with changes in the shape and size of paraffin crystals. In addition, oil viscosity decreases and its flowability at low temperatures improves.

Effect of Pour Point Depressant Concentration

One of the important factors affecting the efficiency of pour point depressants is their concentration. Analysis of literature data showed that an increase in additive concentration leads to a noticeable decrease in the oil pour point temperature.

When depressant reagents are introduced in small amounts (up to 0.02 wt.%), an initial decrease in pour point temperature and oil viscosity is observed. Increasing the concentration to 0.04 wt.% allows achieving the maximum effect due to the uniform distribution of additive molecules within the oil system. Table 2 presents the effect of depressant additive concentration on the rheological properties of oil. The results indicate that increasing additive concentration leads to a decrease in oil pour point temperature and viscosity. The maximum efficiency was observed at a concentration of 0.04 wt.%, where the pour point decreased to negative temperatures and viscosity was significantly reduced.

However, a further increase in additive concentration may lead to a decrease in its efficiency due to the saturation of the paraffin crystal surface and changes in the structure of the oil system.

Current Trends in the Development of Pour Point Depressants

At present, new approaches aimed at developing highly effective pour point depressants are being actively explored. One of the most promising directions is the development of composite reagents based on surfactants and polymer components.

The use of by-products and secondary raw materials from the petrochemical and oil-fat industries is of particular interest. The application of such materials makes it possible to reduce the production cost of pour point depressants and improve their environmental safety [17].

Table 2 – **Classification of Modern Pour Point Depressants**

Additive Concentration, %	Pour Point Temperature, °C	Viscosity, mPa·s	Effect
0 (without additive)	+30	46.3	Formation of deposits
0.02	+7	27.7	Improved flowability
0.03	+4	22.1	Optimal effect
0.04	–3	16.6	Maximum reduction

Figure 2 shows the main directions in the development of modern depressant additives. Current research is focused on the creation of multifunctional composite reagents, environmentally friendly additives, and polymer systems capable of simultaneously reducing viscosity and preventing paraffin deposit formation.

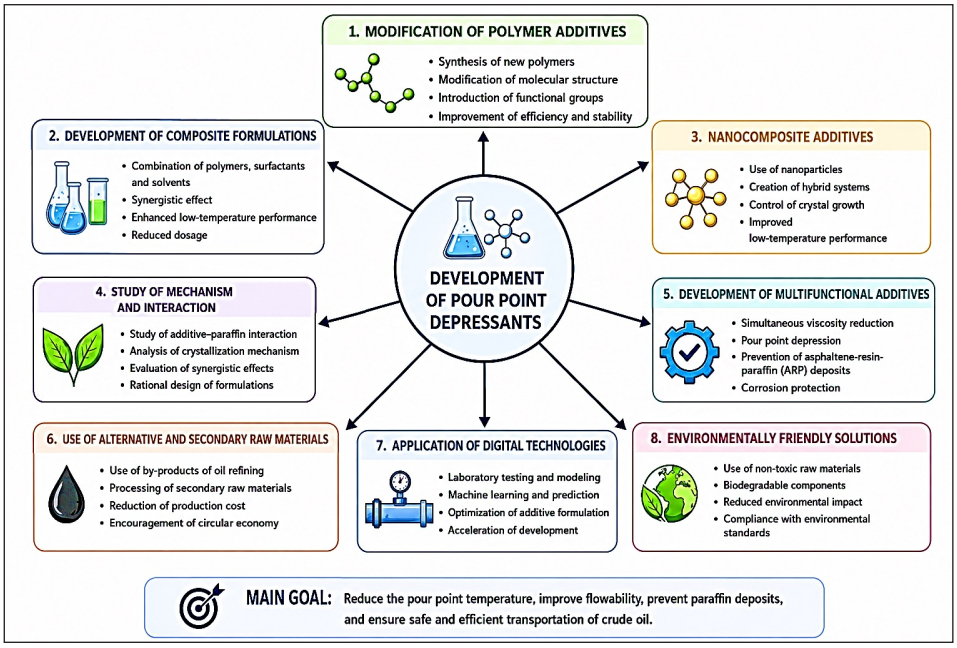

Figure 2 – **The main directions for the development of modern depressive supplements**

In addition, modern studies are aimed at developing multifunctional additives capable of simultaneously reducing the oil pour point temperature, decreasing viscosity, and preventing the formation of paraffin deposits. Such reagents exhibit a complex effect and ensure improved efficiency of oil production and transportation processes [17].

Comparative Analysis of the Efficiency of Different Types of Pour Point Depressants

A comparison of results from various studies showed that polymeric and composite pour point depressants demonstrate the highest efficiency. They provide a significant reduction in oil pour point temperature and improve oil flowability at low temperatures.

As a result of applying pour point depressants:

• the oil pour point decreases by 10-30 °C;

• oil viscosity at positive temperatures decreases by 40-56%;

• the intensity of asphaltene-resin-paraffin deposit formation decreases;
• the efficiency of oil transportation through pipelines increases.

The obtained results demonstrate the high efficiency of modern chemical pour point depressants and confirm their important role in ensuring the stable operation of oilfield equipment.

Conclusions

The analysis of modern studies showed that chemical pour point depressants are an effective means of reducing the pour point temperature of paraffinic crude oils and improving their rheological properties. The use of these reagents makes it possible to decrease oil viscosity, prevent the formation of asphaltene-resin-paraffin deposits, and improve the efficiency of oil production and transportation processes.

It was established that polymeric and composite pour point depressants demonstrate the highest efficiency, and their effect is associated with modifying the structure of paraffin crystals and reducing their ability to aggregate. One of the promising directions is the development of multifunctional depressant formulations and their optimization considering the composition of crude oil and operating conditions.

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