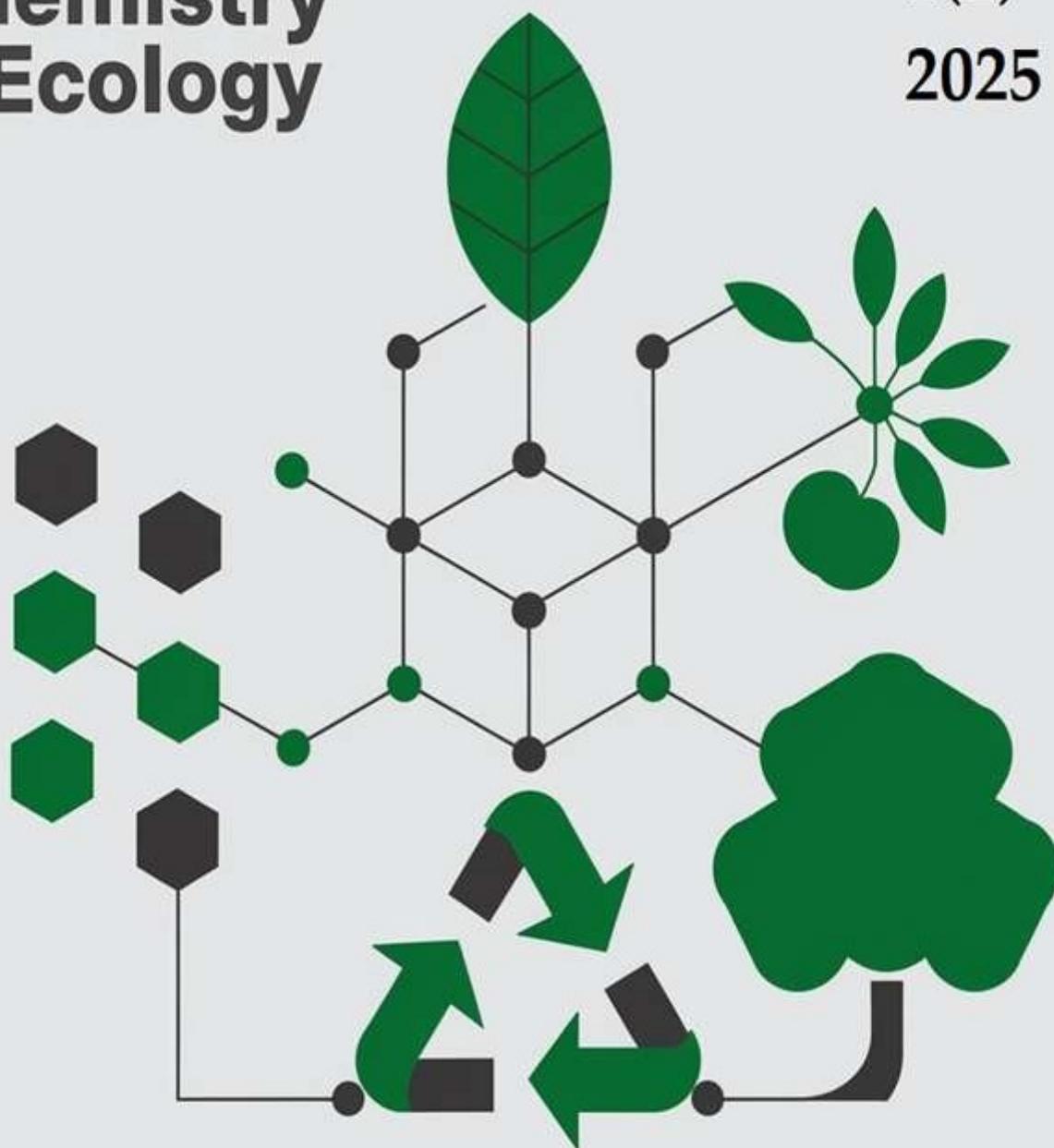


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**INCREASING THE EFFECTIVENESS OF POLYMERIC THICKENING ADDITIVES
FOR MOTOR OILS**

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ANNOTATION

This article discusses innovative approaches to improving the efficiency and stability of polymeric thickeners used in modern motor oils. The main focus is on understanding the molecular interactions between thickeners and different base oil types, including mineral, semi-synthetic, and fully synthetic bases. The interactions with base components were analyzed using rheological and physicochemical methods, and strategies for optimizing their chemical structure and composition were proposed. The study's findings demonstrated that the correct selection of base oils and polymer architecture significantly increases the viscosity index, enhances thermal stability, reduces engine wear, and improves overall fuel and energy efficiency.

POLYMER THICKENERS, MOTOR OILS, VISCOSITY, BASE OILS, OIL FORMULATION

1 Introduction

In today's world, motor oil manufacturers continue to actively research and develop new additives that can maximize engine efficiency and provide protection while meeting strict quality standards. The evolution of motor oils is aimed at improving their performance characteristics, including reducing friction, reducing engine wear and increasing overall energy efficiency. In the context of global efforts to improve the environmental performance of vehicles, special attention is

paid to the creation of oils that help reduce carbon dioxide (CO₂) emissions and other harmful substances into the atmosphere, which is an integral part of the global strategy to combat climate change [3, 4]. Modern motor oils must ensure stable engine operation over a wide range of temperatures, guaranteeing reliable protection against wear and reducing the friction coefficient, which is critical for increasing engine life and performance [5,6]. The effectiveness of the oil under these conditions largely depends on the composition of its base oil and additives. One of the most important components of motor oils are polymer thickeners, which play a key role in maintaining the viscosity characteristics of the oil, which in turn helps improve lubricating properties, stabilise viscosity at different temperatures and protect against wear. However, the effectiveness of these thickeners can vary significantly depending on the type and composition of the base oil [7].

Given the current environmental agenda and the need to reduce carbon dioxide emissions, improving energy efficiency and reducing friction losses are becoming important issues for the automotive industry. The use of lubricants with improved characteristics, such as oils with a low friction coefficient and higher viscosity stability, is one of the most effective methods for achieving these goals. Research shows that friction-related energy losses account for up to 11.5% of fuel consumption in typical passenger car engines, making the issue of reducing friction important for improving overall fuel efficiency [8]. In the context of the need to comply with environmental standards and improve energy efficiency, various additives such as friction modifiers, anti-wear additives and polymer thickeners play a key role. These additives can significantly reduce friction between engine parts, which in turn reduces fuel consumption, improves environmental performance and increases the service life of the vehicle [9, 10]. In particular, the use of polymer thickeners, which are responsible for viscosity stability, can lead to significant improvements in the performance characteristics of oils, especially at high operating temperatures. Thus, this paper discusses methods for increasing the effectiveness of polymer thickeners, as well as their interaction with various base oils. The studies conducted are aimed at optimizing the composition of oils to achieve their improved characteristics, which contributes to both increasing energy efficiency and meeting modern environmental requirements.

2 Materials and research methods

All materials and methods of the study are described in detail. The description of materials and methods should ensure that the studies conducted can be repeated by readers.

2.1 Materials

In this study, a comprehensive methodology was used to analyze the effectiveness of polymer thickeners in motor oils, including several approaches to study the physicochemical properties of the oils and their interactions with base oils and additives. Two types of motor oils with different base oil and additive compositions were selected. The oils were prepared in the laboratory using different base

oils (Group I and Group II) and additives such as polymer thickeners, pour point depressants, antifoam additives, and multifunctional additive packages. All oils were prepared according to precisely defined recipes. The following recipes were used in the study:

Motor oil-1 SAE 10W-40, API CF-4/SG:

Base oils:

I. Base oil II – 46.015% (viscosity 4.74)

II. Base oil II – 20.00% (viscosity 6.26)

III. Base oil I – 25.00% (viscosity 5.35)

Additives:

I. Multifunctional package of additives – 7,

II. Thickener – 1.48%

III. Pour point depressant mixture – 0.3%

IV. Anti-foam additive – 0.005%

Motor oil-2 SAE 10W-40, API CF-4/SG:

Base oils:

I. Base oil I – 90.82% (viscosity 5.35)

Additives:

I. Multifunctional additive package – 7.2%

II. Thickener – 1.48%

III. Depressant mixture – 0.5%

IV. Anti-fouling additive – 0.005%

2.2 Methods

Viscosity at different temperatures, viscosity index, pour point, evaporation rate and other physicochemical properties were determined [11, 12]. To evaluate the viscosity characteristics of oils, methods corresponding to ASTM D445 and ASTM D5293 standards were used. Kinematic viscosity at 100°C and apparent viscosity at -25°C (CCS) were determined using viscometers, which allow evaluating the stability of oil viscosity at different temperatures and operating conditions. These parameters are unique for evaluating the ability of oil to reliably provide lubrication under high temperature conditions and when starting the engine at low temperatures.

Viscosity index (VI) was determined according to ASTM D2270. This indicator characterizes the ability of the oil to maintain a stable viscosity with temperature changes. Oil loss at high temperatures was determined using the Noack method, according to ASTM D5800. This method measures the percentage of oil evaporation at 250°C and helps evaluate its ability to maintain its

properties under prolonged high loads and temperatures. Minimizing oil loss is important for increasing oil and engine life.

To evaluate the low-temperature properties of oils, the pour point was measured according to the ASTM D97 standard. This is an important indicator that shows at what temperature the oil retains its flow properties and can be used in low-temperature conditions.

For a more in-depth analysis of the oil composition, the method of infrared spectroscopy with Fourier transformation (FTIR) was used on Spectrum Two equipment (Perkin Elmer). The spectra obtained for the oil samples allowed us to establish the presence of various functional additives, such as depressants, antifoam additives, detergents and antioxidant additives, as well as thickeners. The analysis of the IR spectra provided information on the structural features of polymer thickeners and their interaction with base oils.

3 Results and discussion

The experimental results confirmed that the efficiency of polymeric thickeners is influenced by the composition of the base oils [13].

3.1 Physicochemical characteristics of motor oils

Table 1 presents the main physicochemical parameters for two samples of motor oils containing different formulations of base oils and additives.

Table 1 – Physicochemical Characteristics of Motor Oils

Nº	Indicator	Sample 1 (Oil-1)	Sample 2 (Oil-2)
1	Kinematic Viscosity at 100°C (mm ² /s)	13,27	14,52
2	Apparent Viscosity (CCS) at -25°C (mPa·s)	4839	8903
3	Viscosity Index	158	148
4	Noack Volatility Loss (%)	8,9	9,7
5	Total Base Number (mg KOH/g)	9,4	8,8
6	Alkalinity (mg KOH/g)	9,9	9,5
7	Sulfated Ash Content (%)	1,37	1,41
8	Mass indices of mechanical additives, %	0.0031	0.0034
9	Mass index of water, %	traces	traces
10	Pour Point Temperature (°C)	-43	-41
11	Flash Point Temperature (°C)	231	248
12	Oil foaming stability, cm ³ 1. 24 °C	1. 0/0	1. 0/0

	2. 93 °C 3. From 93°C to 24 °C	2. 10/0 3. 0/0	2. 20/0 3. 0/0
13	Mass fraction of calcium, %	0,299	0,304
14	Mass fraction of zinc, %	0,113	0,123
15	Mass fraction of phosphorus, %	0,102	0,115
16	Density at 20 °C, kg/m ³	861,9	865,5
17	Density at 15 °C, kg/m ³	865,1	868,6
18	ASTM color scale	2,0	2,0

Experiments (Table 1) have shown that the effectiveness of polymeric thickeners depends on the composition of the base oils [13]. Analysis has shown that oils with a high synthetic content (especially Group II oils) have better viscosity stability, lower evaporation rates, and higher viscosity indices [14]. The use of depressant and multifunctional additives has helped to improve the low-temperature properties of oils.

The kinematic viscosity at 100°C meets the established standards, ensuring reliable lubrication of engine components under high-temperature conditions (Figure 1). According to SAE 10W-40 requirements, the apparent viscosity at -25°C (CCS) should not exceed 7000 mPa·s. For **Sample 1**, the apparent viscosity complies with the standard, while **Sample 2** exceeds the norm, indicating a defect in this sample.

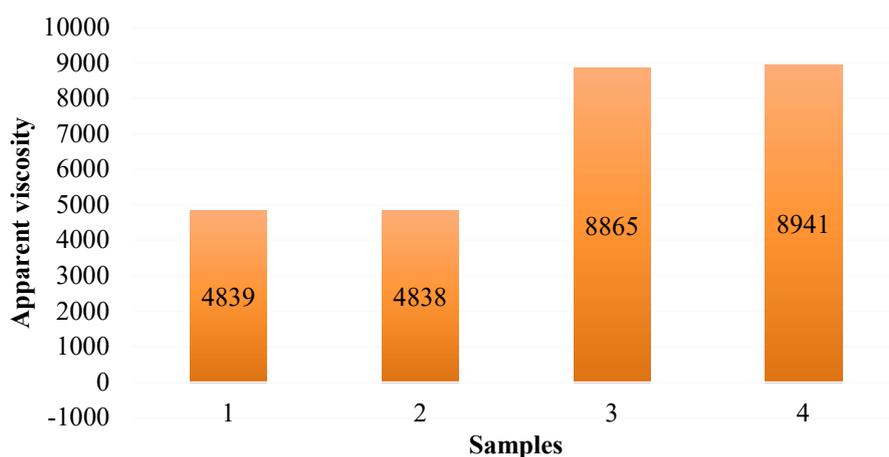


Figure 1 – Apparent viscosity of engine oil at temperature -25°C (CCS)

A higher viscosity index indicates better stability across various temperatures (Table 1). The Viscosity Index for Sample 1 is 158, which is above the normal level of 140 and indicates better performance in maintaining viscosity at different temperatures compared to Sample 2, which has an index of 148.

Low oil consumption at high temperatures according to Noak is in accordance with the standards (not more than 13%), which extends the service life of the oil. The alkaline number is an important indicator for neutralizing acidic products. It complies with the standards (not less than 8). The sulfated ash content is at a normal level (not more than 1.5%), which reduces the likelihood of deposits in the engine. The pour point ensures the stability of the oil at low temperatures. The normal level is below -35°C , the results comply with the standard. The flash point is important for assessing the thermal stability of the oil. The minimum norm is 220°C , the results comply with the requirements. The oil has good foaming resistance, which prevents the formation of air bubbles in the lubrication system. The elemental composition confirms the presence of detergent and anti-wear additives.

The study demonstrates that the use of modern polymer thickeners significantly improves the performance characteristics of motor oils. Both oil samples exhibited good stability in terms of viscosity, volatility, and resistance to foaming, ensuring reliable lubrication and protection of engine parts under various operating conditions.

3.2 FTIR Analysis of Motor Oil Samples

This section presents the infrared spectra of the motor oil samples studied in this research, with a focus on identifying characteristic absorption bands that correspond to various molecular components (Figure 2).

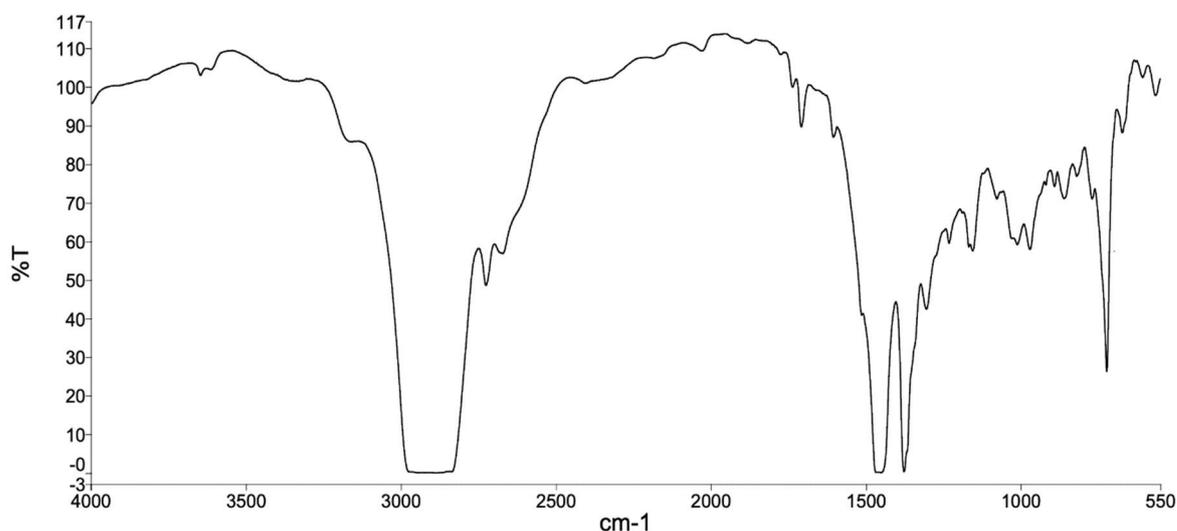


Figure 2 – FTIR spectrum of an oil sample

In the FTIR spectrum of motor oil with additives (Figure 2), characteristic absorption bands are observed, indicating the presence of both base oils and various functional additives included in the formulation. The main peaks in the region of $3000\text{--}2800\text{ cm}^{-1}$ are associated with the stretching vibrations of the C-H bonds in the methyl (CH_3) and methylene (CH_2) groups characteristic of the hydrocarbon base of the base oil. The intensity of these bands depends on the presence of long-chain hydrocarbons present in the base oil and thickener additives.

The peaks at 1465 and 1375 cm^{-1} correspond to the C-H deformation vibrations characteristic of the hydrocarbon structure of the oil. The presence of an intense peak in the region of 1730-1710 cm^{-1} associated with carbonyl groups (C=O) due to the addition of depressant additives indicates the presence of esters used to improve the low-temperature properties of this oil.

The bands in the range of 1400-1300 cm^{-1} are characteristic of sulfonates included in the multifunctional additive packages. They confirm the presence of detergents that prevent the formation of deposits on engine surfaces. Peaks in the region of 1600-1500 cm^{-1} indicate the presence of aromatic compounds characteristic of antioxidants used to prevent oil oxidation (for example, aromatic amines or phenolic compounds).

In the range of 1250-1000 cm^{-1} , bands indicating the presence of boron compounds are observed. These compounds are responsible for anti-wear and antioxidant properties.

The presence of thickening additives is reflected in the increase in the intensity of the bands in the region of 3000-2800 cm^{-1} (C-H), as well as in the appearance of bands in the region of 800-700 cm^{-1} , which indicate the structural features of long-chain polymers such as polyisobutylenes.

Thus, differences in the IR spectra of motor oil samples with additives are due to variations in the additive formulations, including depressants, antifoam agents, detergents, antioxidants, and thickening components.

4 Conclusion

The use of advanced polymer thickeners has significantly improved the performance of motor oils. The modified oils maintain viscosity stability, reduce evaporation rates, and increase wear resistance [15]. It has been found that the effectiveness of oils can be improved by using different base oil formulations. Future studies will be aimed at investigating the compatibility of polymeric thickeners with various base oil.

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МОТОР МАЙЛАРЫНА АРНАЛҒАН ПОЛИМЕРЛІ ҚОЮЛАНДЫРҒЫШ ҚОСПАЛАРДЫҢ ӘСЕР ЕТУ ТИІМДІЛІГІН АРТТЫРУ

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Бұл мақалада мотор майларында қолданылатын полимерлі қоюландырғыштардың тиімділігін арттыру жолдары қарастырылады. Негізгі назар қоюландырғыштардың әртүрлі базалық майлармен әрекеттесуіне бөлінеді. Қоюландырғыштардың базалық компоненттермен өзара әрекеттесуі талданып, олардың құрамын және құрылымын оңтайландыру әдістері зерттелді. Зерттеу нәтижелері базалық майлардың дұрыс таңдалуы тұтқырлық индексін арттыруға, қозғалтқыш бөлшектерінің тозуын төмендетуге және жалпы энергия тиімділігін жақсартуға мүмкіндік беретінін көрсетті.

ПОЛИМЕРЛІ ҚОЮЛАНДЫРҒЫШТАР, МОТОР МАЙЛАРЫ, ТҮТҚЫРЛЫҚ, БАЗАЛЫҚ МАЙЛАР, МАЙ ҚҰРАМЫН ОҢТАЙЛАНДЫРУ

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ПОВЫШЕНИЕ ЭФФЕКТИВНОСТИ ПОЛИМЕРНЫХ ЗАГУЩАЮЩИХ ПРИСАДОК ДЛЯ МОТОРНЫХ МАСЕЛ

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В статье рассматриваются способы повышения эффективности полимерных загущающих присадок, используемых в моторных маслах. Основное внимание уделено взаимодействию загустителей с различными базовыми маслами. Проанализировано взаимодействие загустителей с базовыми компонентами, а также изучены методы оптимизации их состава и структуры. Результаты исследования показали, что правильный подбор базовых масел позволяет повысить индекс вязкости, снизить износ деталей двигателя и улучшить общую энергетическую эффективность.

ПОЛИМЕРНЫЕ ЗАГУСТИТЕЛИ, МОТОРНЫЕ МАСЛА, ВЯЗКОСТЬ, БАЗОВЫЕ МАСЛА,
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CHLORELLA VULGARIS ӨСІРУ ЖАҒДАЙЛАРЫНЫҢ БИОМАССАҒА ЖӘНЕ БИОЛОГИЯЛЫҚ БЕЛСЕНДІ ЗАТТАР ҚҰРАМЫНА ӘСЕРІ

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АҢДАТПА

Chlorella vulgaris құрамында ақуыздың, пигменттердің және басқа да биологиялық белсенді заттардың көп болуына байланысты химия мен экологияда кеңінен қолданылатын зерттеу нысаны болып табылады. Жасуша метаболизмін жақсартуға және өнімділікті арттыруға бағытталған қоректік орталардың химиялық модификациясы табысты өсірудің ең маңызды аспектісі болып табылады.

Зерттеудің мақсаты – *Chlorella vulgaris* өсуіне, биомассасына және химиялық құрамына Тамийя, Богданов және BG-11 қоректік орталарын химиялық модификациялаудың әсерін зерттеу, сонымен қатар несепнәр мен темір нанобөлшектерін қоректік ортаға қосудың биомасса және микробалдырлардың өсуін арттыру үшін тиімділігін бағалау.

Өсірудің физикалық көрсеткіштерін зерттеу кезінде микробалдырлардың ең жақсы өсуіне $28 \pm 2^{\circ}\text{C}$ температурада, жарық фазасы 16 сағат және қараңғы кезеңде 8 сағат, ылғалдылық 29-31%, CO_2 концентрациясы 0,03% болғаны анықталды.

Әртүрлі қоректік орталардың химиялық құрамының әсерін зерттеу нәтижелері Богданов ортасы хлорелланың ең жоғары өсуі мен биомассасын алу үшін оңтайлы екендігін көрсетті. Қоректік ортаны модификациялау барысында ақуыздық биомассаны алу үшін несепнәрның оңтайлы мөлшері 5 г/л болды. Хлорелла биомассасын арттыруға арналған композициялардың оңтайлы концентрациялары мен арақатынасы $3,7 \times 10^{-3}$ М $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$: 0,15% хитозан болып табылды.