**Investigation of the Influence of Complex Additives on the Energy Efficiency of Crankcase Oils**

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**Abstract.** The methodology and results of experimental research of the way to improve energy saving properties of a number of motor oils with the help of local additives are presented. It is investigated: a number of additives which can be obtained at local productions, their interaction with motor oils and sampling. It was obtained that some additives gave good tribological results with no deterioration of other parameters. These data partially support the energy saving properties (losses and fuel consumption) of motor oils based on the balance of oil temperature in the engine crankcase.

**Keywords:** Energy-efficient motor oils, additives, sediments, viscosity, tribological properties, friction, wear resistance, fuel economy, environmental and economic efficiency

# INTRODUCTION

One of the key factors ensuring the stable and trouble-free operation of an engine during its service life is the use of lubricating products. These substances reduce frictional forces during the interaction of engine parts by forming a protective layer on the surfaces of moving components. They also help dissipate some of the heat generated by friction and wash away mechanical debris formed during operation into the oil sump (crankcase). Among these products, engine oil plays a crucial role. It must ensure efficient engine performance under various temperature conditions, maintain optimal viscosity, and enable quick engine startup at low temperatures. Over time, the composition of engine oil deteriorates, which can lead to a decrease in the engine's performance characteristics. Therefore, extending the service life of engine oils has become one of the important tasks in the field of tribology and engine maintenance. Our research focuses on the development of energy-efficient oils designed for use in gas-fueled diesel-based engines, utilizing locally produced additives.

Fuel economy is directly related to the ability of engine oil to reduce friction in components such as cylinders, bearings, valves, and other parts. When a full oil film is present between the surfaces, hydrodynamic lubrication takes place—here, viscosity is a key factor. However, if surface contact occurs, the chemical properties of the oil and the presence of specific friction-reducing additives become crucial [1].

Energy-efficient engine oils are a specialized type of lubricant formulated to reduce frictional forces in the engine, improve fuel economy, and minimize environmentally harmful emissions. These oils are widely used in the United States, Europe, and Japan. However, direct import of such oils is costly and logistically demanding. The goal of our research is to develop a domestically produced, cost-effective alternative that meets modern performance standards while maintaining competitive quality, in collaboration with local engine oil manufacturers.

# LITERATURE SURVEY

Researchers and Their Contributions

1. Dr. Ali Erdemir (USA); Affiliation: Argonne National Laboratory, USA

Field of Expertise: Tribology, nanostructured friction-reducing materials

Pioneered the development of nanostructured additives for lubricants, particularly boron-based compounds.

Achieved significant reductions in friction through the development of advanced surface coatings and oil additives—contributing to the field of super lubricity.

Enhanced understanding of nanoscale tribological interfaces in engine components.

2. Dr. Hugh Spikes (UK); Affiliation: Imperial College London

Field of Expertise: Surface chemistry, tribological mechanisms, additive science;

Developed the tribofilm theory, explaining how anti-wear films form on surfaces during lubrication.

Conducted foundational research on friction modifier additives, including the widely used zinc dialkyldithiophosphates (ZDDPs).

Influenced international lubricant formulation standards with mechanistic insight into additive behavior.

3. Dr. Martin Priest (UK); Affiliation: University of Leeds, UK

Field of Expertise: High-temperature lubrication, additive-base oil interactions

Investigated the synergistic effects of base oils and additives under thermally stressed conditions.

Participated in EU-funded projects focused on friction reduction and fuel economy improvement in internal combustion engines. Contributed to advancing lubricant testing protocols and real-engine application studies.

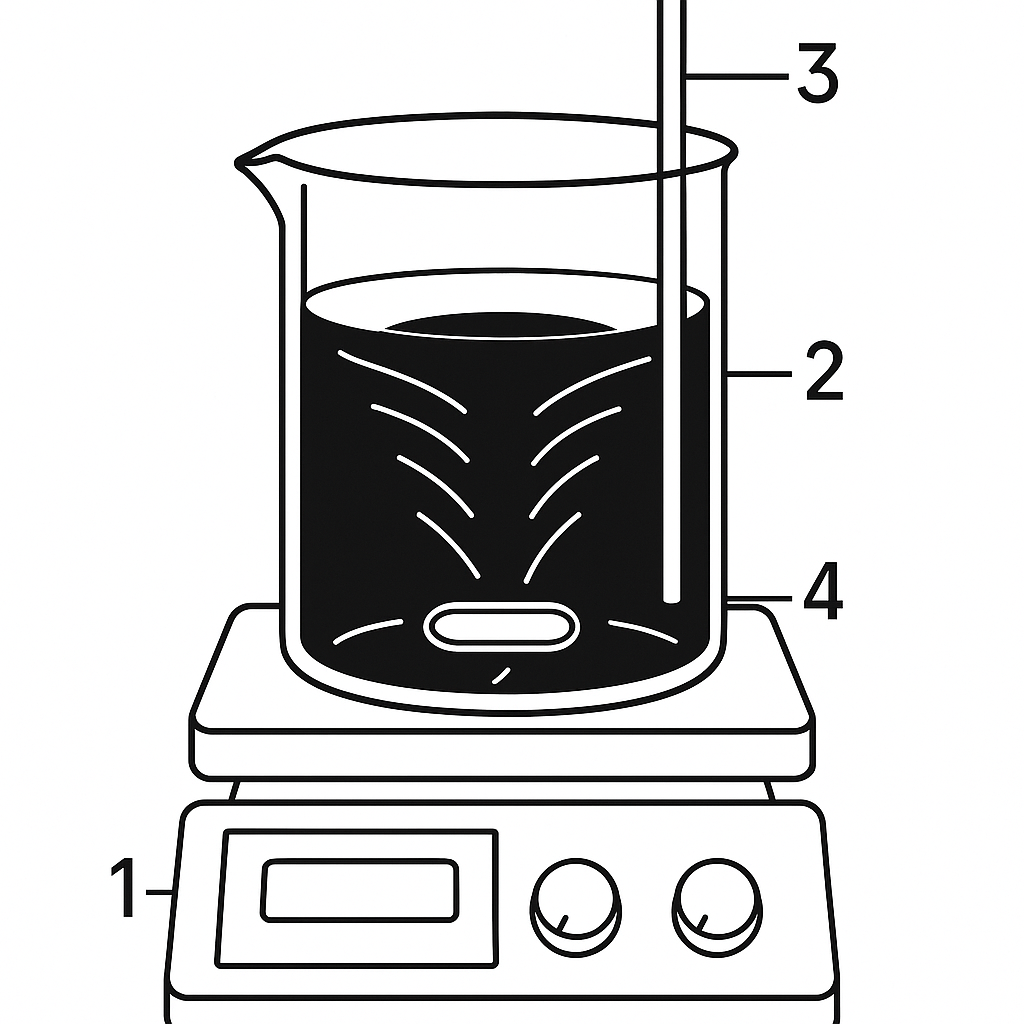
**Energy-efficient engine oil is not merely an industrial product but the culmination of decades of scientific advancements in the fields of tribology, lubricant chemistry, and nanotechnology.** Behind every formulation lies a foundation of rigorous research, peer-reviewed publications, laboratory testing, and the tangible contributions of scientists from around the world.

**RESEARCH METHOD**

During the research process, a selection of specific additives was made based on both international experience and the availability of local raw materials. Initially, the interactions between these additives and the base engine oil were studied, and those additives that demonstrated adverse effects were excluded from further experimentation [2].

An optimal methodology for incorporating the selected additives into engine oils was developed in accordance with established standards. This methodology considered the following key parameters:

* A defined temperature range, based on the properties of both the engine oil and the additive;
* Appropriate additive concentration levels;
* Controlled increase in mixer rotation speed during the blending process;
* Duration of the blending and absorption phases;
* And other relevant process variables.



**FIGURE 1.** Schematic Representation of the Stand for Adding Additives to Engine Oil

The schematic model above illustrates the process of incorporating additives into engine oil. The experimental setup consists of the following main components: 1. Magnetic stirrer; 2. Flask; 3. Temperature sensor;   
4. Stirring bar (anchor-type)

During the process, each additive was tested under varying conditions—specifically different durations, concentrations, and environmental parameters. Based on the results obtained under laboratory conditions, the additives were classified into three categories: fully soluble, moderately soluble, and poorly soluble.



**FIGURE 2.** The process of preparing energy-efficient engine oil was carried out using a laboratory balance and a magnetic stirrer

During the laboratory procedure, both the engine oil and the additives were measured with precise concentrations. The experimental process was conducted under controlled temperature and stirring frequency conditions, as predefined in the methodological framework.

During the experimental procedures, a range of critical performance factors were taken into account to evaluate the properties of energy-efficient engine oils. These include:

Viscosity refers to the oil’s ability to adhere to internal engine surfaces and retain its chemical and physical properties under various conditions. It significantly influences lubrication efficiency and varies depending on ambient temperature.

Coking tendency is the oil’s propensity to form carbonaceous deposits (such as coke and varnish) on engine components. Lower coking resistance increases the likelihood of harmful deposit formation, which adversely affects engine performance and durability.

Ash content indicates the amount of metallic additive residue that remains after oil combustion. High ash content may lead to deposit formation and increased emissions. According to modern standards, the ash content of engine oil should not exceed 1%.

Anti-wear performance is essential for minimizing mechanical wear on interacting engine components. Additives form a protective film on metal surfaces, reducing direct contact, preventing microcracks, scuffing, and surface deformation.

Detergent properties refer to the oil’s ability to remove varnish-like deposits, sludge, and metallic debris from engine parts, thus maintaining cleanliness within the engine.

Dispersant additives help suspend contaminants such as soot, sludge, and combustion by-products within the oil, preventing them from settling and forming deposits.

Oxidation leads to oil degradation and viscosity increase. Antioxidant additives inhibit oxidation reactions, thereby extending oil life and protecting engine surfaces from oxidative stress.

Corrosion resistance is vital for preventing the formation of rust and other corrosive damage on engine parts. Anti-corrosion additives form a barrier film that preserves the crystalline structure of metal surfaces.

Energy-efficient engine oils reduce internal friction, thus contributing to improved fuel economy and lower emissions. The flash point is the temperature at which the oil emits flammable vapors. High-quality oils typically exhibit a high flash point, indicating greater thermal stability and fewer low-boiling-point impurities.

The pour point defines the lowest temperature at which the oil remains fluid. It directly affects viscosity and cold start performance in low-temperature environments. Performance Requirements for Modern Engine Oils:

Given the high-temperature, high-pressure, and chemically aggressive environments in which engine oils operate, they must meet a comprehensive set of performance standards. Contemporary engine oils are expected to exhibit:

High detergent, dispersant, stabilizing, peptizing, and solubilizing capacities to ensure effective removal and suspension of insoluble contaminants, maintaining engine cleanliness;

Superior thermal and thermo-oxidative stability for effective piston cooling, resistance to heat buildup in the crankcase, and prolonged oil change intervals;

Excellent anti-wear properties, including strong oil film integrity, appropriate high-temperature viscosity, and the ability to chemically protect metal surfaces under boundary lubrication conditions while neutralizing acidic oxidation by-products;

Non-corrosive behavior toward engine components both during operation and extended downtime;

Aging resistance, ensuring minimal property degradation under prolonged exposure to operational and environmental factors;

Stable viscosity-temperature behavior, guaranteeing reliable cold start performance, oil pumpability, and effective lubrication under extreme load and temperature conditions;

Compatibility with sealing materials and with catalytic converters used in emission control systems;

High transport and storage stability under regulated conditions;

Low foaming tendency at both high and low temperatures;

Low volatility and minimal oil consumption due to evaporation (enhancing environmental performance) [3].

**The Role of Energy-Conserving Engine Oils in Environmental Protection**

Modern trends in automotive engineering and petrochemistry are increasingly focused not only on enhancing vehicle performance but also on minimizing environmental impact. In this context, energy-efficient engine oils (EEEOs) play a critical role as next-generation lubricants capable of improving fuel economy while simultaneously reducing harmful emissions. Their environmental value goes far beyond simple fuel savings, encompassing multiple dimensions — from raw material composition to compatibility with advanced exhaust aftertreatment systems.

One of the primary environmental benefits of EEEOs is their ability to reduce fuel consumption, which directly correlates with lower carbon dioxide (CO₂) emissions. According to the U.S. Environmental Protection Agency (EPA), low-viscosity engine oils can provide fuel savings of 2.5–3.5% in passenger vehicles. For an annual mileage of approximately 15,000 kilometers, this equates to a fuel saving of around 100 liters, or a reduction of roughly 230 kg of CO₂ emissions per vehicle per year.

EEEOs are typically formulated in accordance with the Low SAPS (sulfated ash, phosphorus, and sulfur) standard—a critical requirement for protecting sensitive exhaust aftertreatment components such as catalytic converters and diesel particulate filters (DPFs). Traditional additive systems (e.g., ZDDP) with high phosphorus content can deactivate or clog these components, shortening their lifespan.

By incorporating alternative additive packages — such as boron compounds and organic molybdenum complexes — Low SAPS oils offer not only improved environmental safety but also robust wear protection and oxidation resistance. This leads to extended oil change intervals, reduced lubricant consumption, and lower volumes of waste oil requiring disposal.

EEEOs are engineered with consideration for the demands of modern powertrains, including gasoline direct injection (GDI), turbocharged, and hybrid engines. Their thermal and chemical stability is essential under stop-start conditions and high-load city driving cycles.

Moreover, these oils enhance the performance and longevity of emission control systems such as EGR (Exhaust Gas Recirculation) and SCR (Selective Catalytic Reduction) by maintaining cleaner combustion and stable operating conditions.

The reduction of internal friction and improved combustion efficiency associated with EEEOs leads to a decrease in the emission not only of CO₂, but also of other harmful pollutants, such as:

CO (carbon monoxide)

NOₓ (nitrogen oxides)

HC (hydrocarbons)

PM (particulate matter)

Studies conducted under the Japan Automobile Research Institute (JARI) have shown that the use of low-viscosity synthetic oils in hybrid powertrains can reduce total air pollution by 10–15% compared to conventional lubricants meeting older API SG/SL standards.

In addition, modern formulations of engine oils are becoming increasingly eco-friendly with regard to their end-of-life disposal. Some manufacturers have begun developing biodegradable esters from plant-based sources, compliant with OECD 301 standards. Although these biobased oils are not yet widely adopted—due to cost and limited thermal stability—they show promising potential for use in municipal fleets and urban utility vehicles.

The Environmental Value of EEEOs is Evident Through Their Ability to:

Reduce the carbon footprint of transportation;

Protect sensitive exhaust aftertreatment components;

Extend engine service life;

Lower toxic emissions;

Decrease the volume of waste oil requiring disposal.

In conclusion, energy-efficient engine oils represent a key element in the sustainable development of the transportation sector and should be regarded as an effective tool in the implementation of global environmental strategies — including the goals of the Paris Agreement and the UN climate action programs aimed at reducing greenhouse gas emissions [5, 6, 7].

**RESULTS AND DISCUSSIONS**

During the experimental process, the kinematic viscosities of engine oils modified with various additives were measured at 40°C and 100°C using a viscometer, in accordance with established laboratory standards. Additionally, taking into account the available equipment and technical conditions of the university laboratory, the flash point of the oil samples was determined using a closed-cup apparatus.

**TABLE 1.** The results of research conducted in the university laboratory

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Experimental Samples | Viscosity, mm²/s, 40˚C | Viscosity, mm²/s, 100˚C | The flash point ˚C | Solubility level |
| CHILON PLATINUM DT SAE 15W-40 API CI-4/SL (1) | 66,7678 | 11,345 | 210 | Base Oil |
| UNO RED G MINERAL SAE 15W40 API SF/CC (2) | 66,0394 | 11,4857 | 195 | Base Oil |
| (1) + ING. KOR.(1%) | 61,56 | 10,86 | 215 | Complete Formulation |
| (2) + ING. KOR.(1%) | 84,1495 | 12,7273 | 202 | Complete Formulation |
| (1) + DOB (1%) | 71,265 | 10,7463 | 217 | Complete Formulation |
| (2) + DOB (1%) | 83,3218 | 12,4155 | 221 | Complete Formulation |
| (1) + Ц,СТ (1%) | 58,54 | 11,218 | 216 | Complete Formulation |
| (2) + Ц,СТ (1%) | 79,699 | 12,73 | 200 | Complete Formulation |
| (1) + СА,СТ (0,5%) | 62,42 | 12,8872 | 210 | Effectively Blended |
| (2) + СА,СТ (0,5%) | 70 | 11,5 | 220 | Effectively Blended |
| (1) + СА,СТ (0,25%) | 70,355 | 11,5077 | 221 | Complete Formulation |
| (2) + СА,СТ (0,25%) | 71 | 11,1 | 215 | Complete Formulation |
| (1) + Ф.П.S..(1%) | 71,753 | 11,017 | 215 | Ineffectively Blended |
| (2) + Ф.П.S..(1%) | 72 | 11 | 210 | Ineffectively Blended |

The table above presents the results of research conducted in the university laboratory. It provides data on the **kinematic viscosity, flash point,** and **blend type** of the selected oil samples. Based on this information, a **comparative diagram** is provided below to visually analyze and interpret the experimental findings.

The preliminary results presented above indicate that, at specific points, the additives introduced into the engine oils exhibited measurable effects. However, it is important to emphasize that although most additives demonstrated good miscibility under the prescribed laboratory conditions, in some cases, minor sediment formation was observed. In other instances, the dissolution process initially appeared successful but later reversed, resulting in the complete precipitation of the additive from the blend.

These findings lead us to conclude that not all laboratory-formulated blends are suitable for practical application. During real-world engine operation, these additives may accumulate—at best within the filtration system, and at worst, between engine components, potentially leading to mechanical malfunctions or damage [4].

**DIAGRAM 1. Comparative diagram of** the results of research conducted in the university laboratory

Following the initial testing phase, samples that demonstrated superior properties were selected for comprehensive analysis. In order to ensure transparent evaluation, the most promising preliminary formulations were labeled as A, B, C, and D. These selected samples were then submitted to “Chilon”, a local engine oil manufacturing company, where further laboratory testing was conducted under controlled industrial conditions.

**TABLE 2.** “Chilon” Local Lubricant Plant: Laboratory-Based Assessment Results

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Parameter | A | B | D | V | Comment |
| Density at 15 °C, kg/m³ | 880.3 | 884.9 | 883.3 | 884.6 | A is the lightest oil |
| Kinematic viscosity at 40 °C, mm²/s | 122.12 | 121.30 | 123.5 | 120.44 | D is the most viscous |
| Kinematic viscosity at 100 °C, mm²/s | 15.83 | 15.78 | 16.05 | 15.84 | All within SAE 40 range |
| Viscosity index | 138 | 138 | 135 | 135 | A and B slightly more stable |
| Acid number (TAN), mg KOH/g | 5.44 | 5.43 | 5.41 | 5.35 | V is slightly milder |
| Base number (TBN), mg KOH/g | 6.3 | 6.3 | 2.15 | 2.15 | A & B are well-detergent; D & V lack TBN buffer |
| Pour point, °C | –22 | –30 | n/a | n/a | B has the best low-temp flow |
| Sulfated ash, % wt | 0.88 | 1.02 | 0.81 | 0.68 | V is the most “Low-SAPS”-friendly |
| Water content, % | 0.002 | 0.002 | 0.002 | 0.002 | Excellent in all samples |
| Solid contaminants, % | 0.002 | 0.002 | 0.002 | 0.002 | All very clean |

The following interpretations are derived from the data presented in the table above:

| Sample | Interpretation |
| --- | --- |
| A | Balanced, medium-SAPS oil, likely SAE 10W-40 or 15W-40, adequate TBN and good base reserve. |
| B | Similar to A but with better cold start (–30 °C) and slightly higher ash → may suit older API SL/CI-4 engines. |
| D | High-viscosity, low-ash oil with poor base reserve — likely a test blend without detergent/dispersants. |
| V | Low-ash, cleanest profile, may contain DOB-DTP (boron additive), intended for modern engines with aftertreatment (DPF/TWC), but requires EP/wear testing. |

# CONCLUSION

Calcium and zinc stearates are excellent soap-based thickeners for greases, but in engine oils they tend to lead to precipitation, excessive ash, and potential issues with LSPI (Low-Speed Pre-Ignition) and aftertreatment systems.

If your target is anti-friction or anti-wear performance, it is strongly recommended to use modern, fully oil-soluble additive packages.

Although zinc stearate dissolves during synthesis, it still poses risks as a marginal engine oil additive:

It may lack durability under thermal/humidity/oxidative cycles typical of real-world engine operation;

It provides little to no improvement in anti-wear (AW) and extreme-pressure (EP) performance compared to traditional ZDDP.

While the laboratory formulation has demonstrated actual stability, further validation is necessary—especially through a 4-week cyclic stress test (−40 to +150 °C, 1% water, 5000 rpm shaker).

Until the formulation successfully passes standardized tests such as Sequence VIII/IX, it remains associated with significant commercial risk.

Boron Dithiophosphate (DOB): A Proven Fuel-Efficient Additive

Provides up to 2–3% fuel savings in mass-production engines at just 0.3–0.5 wt% concentration;

Retains fuel economy benefits more effectively over time than conventional ZDDP;

Complies with Low-SAPS / Low-Zn regulations and contributes to extended catalyst life.

Strategic Objective: Achieve compliance with ILSAC GF-6B and ACEA C6 specifications while ensuring fuel economy improvements.

DOB-DTP, or its hydrolysis-resistant EDTP analogue, represents one of the most effective and industry-validated tools currently available on the lubricant additive market.

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