THE ROLE OF INNOVATIVE ADDITIVES IN IMPROVING TRIBOLOGICAL PROPERTIES OF SYNTHETIC DIESEL FUELS

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Abstract. Currently, synthetic liquid fuels (SLF) are widely recognized globally as an alternative to traditional petroleum products due to their environmental friendliness, high combustion efficiency and low emission levels. In particular, fuels obtained from natural gas through GTL (gas-to-liquid) technology are increasingly used in transport, industry and military sectors. However, the lack of aromatic compounds and heavy fractions present in fuels obtained from natural oil in the composition of SLFs leads to poor lubricating properties. This can negatively affect the performance of engines and mechanisms, and cause increased friction and wear. This article focuses on research and development work on improving the lubricating properties of synthetic fuels. In particular, existing approaches, technological methods and their advantages for improving the tribological properties of SLFs using additives synthesized from local raw materials are analyzed. The research results may have important scientific and practical significance in increasing the efficiency of synthetic fuels, accelerating their implementation, and ensuring energy security.

Аннотация.В настоящее время синтетические жидкие топлива (СЖТ) широко признаны в мире как альтернатива традиционным нефтепродуктам благодаря своей экологичности, высокой полноте сгорания и низкому уровню выбросов. В частности, топлива, получаемые из природного газа по технологии GTL (gas-to-liquid), все чаще используются в транспорте, промышленности и военной сфере. Однако отсутствие в составе СЖТ ароматических соединений и тяжелых фракций, присутствующих в топливах, получаемых из природной нефти, приводит к плохим смазочным свойствам. Это может негативно влиять на работу двигателей и механизмов, вызывать повышенное трение и износ. В данной статье рассматриваются научно-исследовательские и опытно-конструкторские работы по улучшению смазочных свойств синтетических топлив. В частности, анализируются существующие подходы, технологические приемы и их преимущества для улучшения трибологических свойств СЖТ с использованием присадок, синтезированных из местного сырья. Результаты исследований могут иметь важное научное и практическое значение для повышения эффективности синтетических топлив, ускорения их внедрения и обеспечения энергетической безопасности.

Keywords: Synthetic liquid fuel, GTL, lubricant, domestic raw materials, molybdenum oxide, sulfur, HFRR

Ключевые слова: Синтетическое жидкое топливо, GTL, смазывающая способность, местное сырье, оксид молибдена, сера, HFRR

Introduction. In the 21st century, against the background of increasing demand for energy resources and aggravating environmental problems, the need for alternative, environmentally friendly and efficient fuels is growing. In this regard, synthetic liquid fuels

(SLF), in particular, fuels obtained from natural gas using GTL (Gas-to-Liquid) technology, are of great interest in the global market. SLF are characterized by a high level of purity, low sulfur content, high cetane number and reduced emissions of harmful substances during combustion. However, the absence or extremely low content of aromatic hydrocarbons in these fuels significantly reduces their lubricating properties compared to natural petroleum products. This leads to poor performance, accelerated wear and tear, and increased maintenance costs in engines and other friction mechanisms. Therefore, improving the tribological (anti-friction) properties of synthetic liquid fuels, i.e. increasing their lubricating ability, is one of the urgent tasks facing modern fuel technologies. Today, research is being conducted in this direction on a number of approaches, including the development of effective additives, the use of local raw materials, and the formation of new composite compositions. This article analyzes the need to improve the lubricating properties of SLF, existing problems, ways to overcome them, and the prospects for additives synthesized from local raw materials.

Literature review. In recent years, synthetic liquid fuels (SLF), especially products obtained using GTL (Gas-to-Liquid) technology, have been the focus of scientific and practical research not only due to their environmental friendliness, but also due to their role in ensuring energy security. As a result of studies conducted by foreign scientists (J.B. Fang, K. Seddon, M. Dry, etc.), it has been proven that GTL fuels provide efficient combustion in internal combustion engines due to their high cetane number, low aromatic content, and near-zero sulfur content [1,2]. However, one of the main disadvantages of these fuels is their low lubricity. Research shows that aromatic and heavy fractions present in natural petroleum products serve to increase lubricity, while synthetic fuels do not contain these components [3]. Therefore, improving tribological properties by introducing special additives into the composition of SLF is one of the current directions of modern fuel chemistry. Studies by A.A. Zolotov and S.V. Dronov [4] have shown the use of bioadditives based on esterified vegetable oils as effective lubricant components for GTL fuels. In addition, Uzbek researchers (N.A. Karimov, B.M. Shukurov, etc.) have reported on the practical effectiveness of additives synthesized from local raw materials - cottonseed oil, oil refining waste, and natural hydrocarbons [5]. The following approaches are being widely studied to improve the lubricating properties of SLF:

1. Use of compounds such as esters, alkanolamides, sulfonates as additives [6];
2. Enrichment of SLF composition using bio-oils and their modified derivatives[7];
3. Nanotechnological approaches – for example, the effect of additives based on dispersed nanoparticles [8].

Also, international ISO and ASTM standards recommend a number of test methods (Ball-on-disk, HFRR - High Frequency Reciprocating Rig, etc.) to assess the lubricity of SSY, and testing using these methods is widely used [9].

Research methodology. Synthetic liquid fuels, in particular those produced using GTL (Gas-to-Liquid) technology, have low lubricity due to the low content of sulfur and other natural lubricating components. Uzbekistan GTL diesel has almost no sulfur content (5 mg/kg). This leads to increased friction in the engine and fuel system, accelerated wear processes, and reduced efficiency. To prevent such inconveniences, chemical additives that increase lubricity are added. Chemical additives that increase lubricity mainly consist of esters, carboxylic acids, higher fatty acids, alcohols, surfactants, colloidal and polymer

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additives. It performs the functions of reducing friction, protecting contact between surfaces, preventing the deposition of solid particles and ensuring their uniform distribution in the fuel or oil, ensuring the long-term stability of the additive, protecting against oxidation, and balancing chemical reactions or adapting to specific conditions. If I were to describe my approaches to improving the lubricity of synthetic fuels based on molybdenum sulfide, I would say that molybdenum sulfide (MoS_2) is a solid substance with high lubricity, and its nano-sized dispersions, when added to synthetic fuels, reduce friction and slow down the wear of engine parts[10]. The following raw materials are used for the synthesis of molybdenum sulfide in the liquid phase: Molybdenum oxide (MoO_3) – obtained from the Almalyk Mining and Metallurgical Combine. Granular sulfur (S) – obtained from the Shurtan gas and chemical complex. These two chemical reagents are considered local raw materials and play a key role in achieving efficiency. MoS_2 is synthesized as a result of the reaction of MoO_3 and S in an alkaline environment. In this process, MoS_2 is formed in the form of small particles, and dispersants are added to stabilize it. Dispersants and stabilizers are selected to ensure that the MoS_2 nanoparticles are evenly distributed in the fuel. Oleic acid – A natural fatty acid that helps MoS_2 particles stay dispersed. Polymer additives (PMA, PIB) – Additives based on polymethacrylates or polybutenediamine prevent the aggregation of nanoparticles. The lubricating performance of MoS_2 dispersions added to synthetic fuels is evaluated by the following HFRR (High-Frequency Reciprocating Rig) Test. The test is performed in accordance with ISO 12156-1 (HFRR)[11] and ASTM D6079 standards. The test involves the frictional movement of a steel ball and disc in a sample fuel placed in a test chamber for 75 minutes at a frequency of 50 Hz and an amplitude of 200 μm. The coefficient of friction (COF) and wear scar diameter (WSD) are automatically recorded during the process. WSD is measured using an optical microscope. The coefficient of friction is compared. If the WSD is reduced when MoS_2 dispersion is added → the lubrication properties are improved[12].

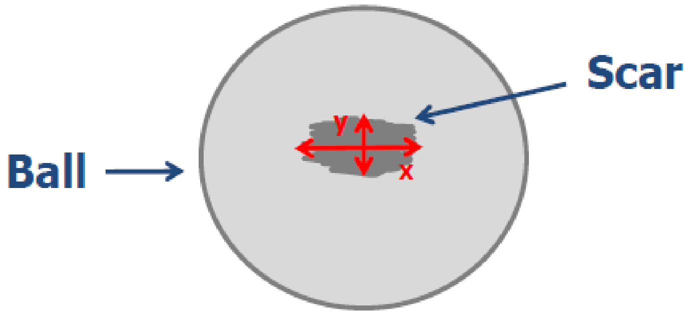

Figure 1. Appearance of friction marks using an optical microscope.

Conclusion. Dispersions of MoS_2 nanoparticles are an effective additive to improve the lubricity of GTL fuels. The stability of the MoS_2 dispersion, synthesized on the basis of molybdenum oxide and sulfur, is ensured by the use of oleic acid and polymer dispersants. This approach is recommended as an innovative solution to increase the reliability of fuel systems and reduce friction in the engine. It shows that additives developed using local raw materials can improve the lubricity of SLF while maintaining its technical and environmental advantages. In particular, molybdenum oxide and sulfur-based modifiers produced in Uzbekistan are one of the promising areas, and additional research is needed to improve their effectiveness. In the future, it will be important to continue research to develop more effective and environmentally friendly additives.

References:

1.Fang, J., & McCormick, R. L. (2006). Spectroscopic Study of Lubricity Additives in Diesel Fuels. Energy & Fuels, 20(1), 48–53.

2.Dry, M. E. (2002). The Fischer–Tropsch process: 1950–2000. Catalysis Today, 71(3-4), 227–241.

3.Seddon, K. R. (2003). Ionic Liquids for Clean Technology. Journal of Chemical Technology and Biotechnology, 68(4), 351–356.

4.Золотов А.А., Дронов С.В. (2018). Биоразлагаемые присадки на основе растительных масел для синтетических дизельных топлив. Вестник Томского политехнического университета, №5, с. 66–71.

5.Каримов Н.А., Шукуров Б.М., Усманов Ф.Б. (2020). Исследование эффективности местного сырья в качестве добавок к синтетическим топливам. Журнал "Нефтегаз", №3, с. 44–49.

6.Patel, H. R., & Sarathi, R. (2010). Development of Lubricity Enhancers Using Esters for Ultra-Low Sulfur Diesel. Industrial & Engineering Chemistry Research, 49(12), 5825–5830.

7.Ali, Y., & Hanna, M. A. (1994). Alternative Diesel Fuels from Vegetable Oils. Bioresource Technology, 50(2), 153–163.

8.Zhang, Q., Wang, D., & Zhao, W. (2017). Nanoparticle Additives in Fuel: Improving Tribological Properties of Diesel. Tribology International, 109, 509–517.

9.ASTM D6079 – 20. Standard Test Method for Evaluating Lubricity of Diesel Fuels by the High-Frequency Reciprocating Rig (HFRR). ASTM International, USA.

10.Martin, J. M., & Donnet, C. (2000). "Superlubricity with MoS_2-based Nanoparticles." Wear, 245(1-2), 107–119.

11.ISO 12156-1:2018 – "Diesel fuel—Assessment of lubricity using the HFRR method."

12.ASTM D6079-18 – "Standard Test Method for Evaluating Lubricity of Diesel Fuels Using the High-Frequency Reciprocating Rig (HFRR).".