TECHNICAL SICENCES

THE IMPACT OF MODIFICATION OF DIESEL FUELS BY BIOCOMPONENTS AND MAGNETIC FIELD ON THEIR ANTIWEAR AND OTHER PROPERTIES

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https://doi.org/10.5281/zenodo.14947201

Abstract

Biodiesel fuels derived from renewable resources show significant potential to improve the lubricating properties of diesel fuels, reduce wear and tear on fuel equipment, and reduce harmful emissions. The problem statement includes the study of the effect of biodiesel fuels and treatment of magnetic field on the antiwear properties and other characteristics of diesel fuels. Treatment of magnetic field is a promising approach that improves the molecular structure of fuel, increases its lubricating properties, and reduces friction and wear of engine parts. The combination of these technologies can help create new fuel systems with improved technical, economic and environmental performance.

Keywords: biodiesel, magnetic field, antiwear properties, diesel fuel, synergistic effect.

Introduction.

In the face of increasing environmental restrictions and the need to reduce harmful emissions, the use of alternative fuels such as biodiesel is attracting increasing attention. Anti-wear properties are one of the key reliability criteria. Biodiesel can reduce wear of parts. In addition, adding biodiesel to traditional fuel helps improve environmental performance. However, along with numerous advantages, the use of biodiesel is associated with a number of challenges. For example, biodiesel has worse low-temperature properties, which may limit its use in cold climates. In addition, the presence of oxygen-containing molecules in biodiesel may increase its corrosion activity. Another promising technology that complements the properties of biofuels is the treatment of diesel fuel with a magnetic field. It allows you to change the molecular structure of the fuel, improving the combustion process and helping to reduce wear of engine components. Research into the effects of biodiesel and magnetic field treatment on the anti-wear and other performance properties of diesel fuels is important for improving modern fuel systems.

Problem statement.

Traditional diesel fuels, although efficient in terms of energy density, are characterized by high levels of greenhouse gas emissions and dependence on fossil resources. The relevance of research into alternative approaches to improving diesel fuels is due to the need to solve environmental and technical problems. The use of biodiesel fuel is becoming an important tool in reducing harmful emissions and improving lubricating properties. However, biofuels have certain limitations, such as increased corrosion activity and low-temperature properties, which requires additional technological solutions to optimize its use. One of the promising areas is the magnetic field treatment of diesel fuel, which improves the physicochemical characteristics of the fuel. The study of the interaction of biodiesel fuels and magnetic field treatment to improve the anti-wear properties of diesel fuels is an extremely important task. This allows not only to solve current technical problems, but also to lay the foundation for creating innovative solutions in the field of fuels and lubricants

Analysis of researches and publications.

The study of the effect of biofuels and magnetic field treatment on the anti-wear and other properties of diesel fuels is based on numerous scientific works and developments. Analysis of the available literature allows us to highlight key aspects and directions for the development of this topic.

• Study of fuel composition and its effect on operational properties.

One of the earliest approaches to the analysis of effect of fuel composition to the formation of deposits and wear of engine parts was carried out by Eltinge L., Gray D. and Taliaferro H. in the work "How Fuel Composition Affects Diesel Deposits and Wear" [1]. This study became the basis for further work focused on the relationship between fuel composition and its tribological properties. Modern approaches to improving the lubricating properties of fuels demonstrate the effectiveness of using nanomaterials. Hou X., Ma Y., Bhandari G., Yin Z., Dai L., Liao H., Wei Y in their work investigated the properties of graphene additives to low-sulfur fuels using plasma-assisted milling methods [2]. The results showed a 20% reduction in the friction coefficient, which confirms the promising nature of such solutions.

• The effect of biofuels on the tribological properties of diesel fuels.

Biofuels, due to the presence of fatty acid methyl esters, have significant potential for improving lubricating characteristics. Sruthi H., Dalimba U.K., Hegde P. investigated the effectiveness of methyl oleate-based lubricating additives for ultra-low-sulfur diesel fuels (ULSD) [3]. The results showed that the introduction of such additives provides a 15%

reduction in wear of fuel system components. Goodrum J.W., Geller D.P. [4], as well as Mei D., Luo Y., Shen X., Lu D., Yuan Y [5] analyzed the effect of various methyl esters on the lubricating properties of diesel fuels. The studies confirmed that the addition of methyl esters contributes to a 10–20% reduction in wear of plunger pairs.

• Effect of magnetic field treatment on the physicochemical properties of fuel.

Ramar K., Subbiah G. [16] investigated the effectiveness of magnetic field treatment of biodiesel on engine performance. It was noted that the magnetic field increases energy efficiency by 8% and reduces CO and HC emissions by 12% and 15%, respectively.

• Synergistic effect of biofuel use and magnetic field treatment.

The combination of biofuel and magnetic field treatment is considered a promising direction in the work of El-Fakharany M. K., Abdelrazek A. S., Baz F. B., Gad M. S. [12]. The authors investigated the effect of combining Nano-TiO_2 with biodiesel under magnetic field treatment.

Analysis of scientific articles demonstrates the versatility of approaches to solving the problems of wear and improving the operational properties of diesel fuels. The synergistic approach, which combines the use of biofuels and magnetic field treatment, shows significant potential for increasing the reliability and efficiency of engine operation. Despite numerous studies, the issue of optimizing the composition of biofuels and magnetic field treatment parameters to achieve maximum efficiency in reducing wear of fuel systems, improving engine stability and minimizing emissions of harmful substances remains open.

The aim of the article is to study the impact of the use of biodiesel fuels and magnetic field treatment on the anti-wear, physicochemical and environmental properties of diesel fuels in order to optimize their composition and treatment technology.

The antiwear properties of diesel fuel play a key role in ensuring reliable and long-lasting operation of diesel engines. Insufficient lubricity of the fuel can lead to increased wear of fuel system components such as fuel pumps and injectors, which in turn increases maintenance and repair costs.

According to a study published in the journal SAE International entitled "How Fuel Composition Affects Diesel Deposits and Wear" [1], 20,000 hours of testing were conducted on six automotive diesel engines, which showed how the sulfur content, aromatics, and average boiling point of the fuel affect deposits and wear. It was found that sulfur increases deposits and wear in these engines under various operating conditions. Higher aromatics and average boiling points increase deposits at certain points in the engines, but have little effect on wear.

A study published in the journal Processes under the title "Preparation and Tribological Properties of Graphene Lubricant Additives for Low-Sulfur Fuel by Dielectric Barrier Discharge Plasma-Assisted Ball Milling" [2] indicates that low sulfur content in fuel impairs its lubricating properties. To improve these properties, the authors propose the use of graphene additives that reduce the coefficient of friction and the wear diameter.

A study by Goodrum J.W. and Geller D.P., presented in the paper "Influence of fatty acid methyl esters from hydroxylated vegetable oils on diesel fuel lubricity" [4], confirms that the addition of FAME to diesel fuel improves its lubricating properties. The authors found that biodiesel components form a lubricating film that significantly reduces wear of contacting surfaces, especially in injectors and fuel pumps.

Studies confirm that the use of biodiesel blends helps reduce wear of diesel engine components. In particular, the study by Mujtaba et al., described in the article "Effect of Additivized Biodiesel Blends on Diesel Engine Performance, Emission, Tribological Characteristics, and Lubricant Tribology", indicates that a mixture of diesel fuel with biodiesel in the ratio of B30 reduces the friction coefficient by 6.72%. The use of biodiesel with the addition of TiO_2 nanoparticles improves lubricating properties and reduces wear of friction surfaces [6].

Geller D.A. and Goodrum J.W. in the article "Effects of specific fatty acid methyl esters on diesel fuel lubricity" [7] studied the influence of individual FAMEs on the properties of diesel fuel. The authors found that long-chain esters demonstrate the highest efficiency in reducing the coefficient of friction and increasing the service life of fuel equipment. Studies confirm that the use of FAME is an effective means of reducing wear, especially in the case of ultra-low sulfur diesel fuel.

A study by Rao et al., presented in the article "Effect of Different Biodiesel Blends (80% Diesel + 20% Biodiesel) on Tribological Property of I.C. Engine Components", shows that the use of B20 significantly reduces wear of piston rings and cylinder surfaces due to improved lubricating properties of the fuel. The study showed that the use of B20 reduces microwear by 15% compared to the use of conventional diesel fuel [8].

Another study by Kinoshita et al., published in the article "The Effect on Diesel Injector Wear, and Exhaust Emissions by Using Biodiesel Fuel", shows that the addition of biodiesel to diesel fuel significantly reduces injector wear. The authors note that biodiesel provides stability of the lubricating film even within the limits of boundary lubrication [9]. Therefore, the use of biodiesel fuel blends significantly reduces the coefficient of friction and wear of engine components, which contributes to increasing their resource and efficiency.

The lubricating properties of esters are improved in the presence of monoglycerides and free fatty acids. With increasing unsaturation and molecular weight of esters, their lubricating properties increase [10].

Long-term use of biodiesel blends, such as B20, can have a positive effect on engine life. In particular, studies show that the use of biodiesel reduces wear on engine components such as pistons, piston rings and fuel injectors. The study "Impact of Biodiesel Blended Fuels on Combustion Engines in Long Term" states that the use of biodiesel blends leads to a reduction in wear and deposits on critical engine parts, which can increase the overall engine life by 5-10% [11].

The study “Impact of Nano-TiO_2 Combination with Biodiesel on Diesel Engine Performance and Emissions Under Fuel Magnetism Conditioning” found that the use of biodiesel (B20) in combination with magnetic field treatment of the fuel provides a 30% reduction in wear of fuel system parts compared to pure diesel fuel. The study conducted experiments on a diesel engine under various operating conditions. For B20 biodiesel with magnetic field treatment, the friction coefficient decreased to 0.28 compared to 0.40 for untreated diesel fuel. In addition, the content of nitrogen oxides in exhaust gases decreased by 18%, and fuel economy was up to 10% [12].

The magnetic field contributes to a change in the electronic structure of oxygen-containing molecules, which reduces their reactivity and, as a result, an aggressive effect on metal engine components. The study presented in the article “Bio-Nanoparticles Mediated Transesterification of Algal Biomass for Biodiesel Production” confirms that the effect of a magnetic field on biodiesel obtained using nanocatalysts reduces the amount of peroxides and free fatty acids in its composition [13]. This contributes to the stabilization of oxygen-containing molecules, which are the main sources of the formation of corrosive compounds. As a result, the level of corrosion wear of metal surfaces is reduced by 15% compared to untreated biodiesel. In addition, according to the article “Effect of Biodiesel Ester Structure Optimization on Low Temperature Performance and Oxidation Stability”, optimization of the structure of biodiesel esters in combination with magnetic field treatment significantly improves its oxidative stability [14]. After magnetic field treatment, such biodiesel demonstrates improved anti-corrosion properties, and stabilization of oxygen-containing molecules after magnetic exposure ensures the formation of a protective film on metal surfaces [15]. Therefore, the magnetic field plays an important role in increasing the stability of oxygen-containing molecules of biodiesel, which not only reduces the corrosive effect and improves the overall performance of the fuel.

Thus, the use of biodiesel provides improved economic and environmental performance of diesel engines. However, to achieve optimal results in different operating conditions, it may be advisable to consider additional fuel treatment methods. Biodiesel contributes to the reduction of harmful emissions. However, biodiesel has worse low-temperature properties compared to traditional diesel fuel, which may complicate its use in cold climates.

A study by Ramar K. and Subbiah G showed that the use of magnetic field treatment of biodiesel blends significantly improves the calorific value of the fuel. When using a B40 blend with magnetic field treatment, the brake heat efficiency increased by 8% compared to untreated fuels [16]. This indicates an increase in the energy efficiency of the engine, since the magnetic field orders the molecular structure of the fuel, which contributes to more complete combustion. Another study published in Materials Transactions (2015) indicates that a 15.89% reduction in smoke and a 12.85% increase in O_2 in exhaust gas reduces engine deposits [17]. A study “A study of magnetic field influence on performance and emission using biodiesel in DI diesel engine” found that CO emissions were reduced by 12% and HC emissions by 15%. This is due to the more complete combustion of the fuel provided by magnetic field treatment and the reduction in the sulfur content of biodiesel.

Marine biofuel trials conducted by the Singapore Decarbonization Center (2024) confirm the readiness of biofuels for use in shipping. The tests showed a 7% increase in engine efficiency due to improved combustion. The study “Magnetic Nanocatalysts for Biofuel Production” notes that the use of magnetic nanocatalysts can significantly improve the efficiency of the transesterification process for biofuel production. This technology provides a 25% increase in productivity compared to conventional methods, but its cost is still high for mass implementation [18]. In the study “The Effect of Biofuel Production on Greenhouse Gas Emission Reductions”, the use of second-generation biofuels allows for a reduction in CO_2 emissions by 8–12% compared to traditional fossil fuels [19]. This efficiency is achieved due to the closed carbon cycle. Also, the study “Biofuels & Greenhouse Gas Emissions: Myths versus Facts” notes that biofuels can reduce emissions of other harmful gases, such as methane and nitrogen oxides, by 5–10%, which provides additional environmental benefits [20].

Conclusions.

It has been established that the modification of diesel fuels with biocomponents significantly improves the lubricating properties of diesel fuel due to the high content of oxygen-containing polar molecules, which allows to reduce the wear of fuel system parts by 10–15%. In addition, biodiesel contributes to the reduction of emissions of harmful substances, which is important for achieving environmental goals. Experimental data confirm that a magnetic field improves fuel combustion, increases the calorific value and stability of engine operation. The combination of biofuels and magnetic field treatment demonstrates a synergistic effect, which allows to reduce the wear of fuel system components by 30%, improve the combustion process and reduce nitrogen oxide emissions by 18%. Such a combined approach increases the economic efficiency of engine operation, reduces maintenance costs and reduces the frequency of maintenance.

Future research includes optimizing the composition of biodiesel fuels, developing new compositions, as well as the use of nanomaterials to stabilize oxygen-containing molecules in biofuels. An important direction is the scaling of magnetic field treatment technologies for industrial use. Additional experimental studies in real conditions will help to confirm the stability and effectiveness of the results obtained. Therefore, the results confirm the prospect of using biodiesel fuels and magnetic field treatment to increase the anti-wear properties of diesel fuels, reduce harmful emissions and improve the efficiency of diesel engines.

References:

1. Eltinge L., Gray D., Taliaferro H. How fuel composition affects diesel deposits and wear. SAE Technical Paper 540187, 1954. DOI: https://doi.org/10.4271/540187

2. Hou X., Ma Y., Bhandari G., Yin Z., Dai L., Liao H., Wei Y. Preparation and Tribological Properties of Graphene Lubricant Additives for Low-Sulfur Fuel by Dielectric Barrier Discharge Plasma-Assisted Ball Milling. *Processes*. 2021. №9. P.272. https://doi.org/10.3390/pr9020272

3. Sruthi H., Dalimba U.K., Hegde P. Efficient Lubricity Improvers Derived from Methyl Oleate for Ultra Low Sulphur Diesel (ULSD). *Pet. Chem*. 2022. №62. PP.1126–1136. DOI: https://doi.org/10.1134/S0965544122090146

4. Goodrum J.W., Geller D.P. Influence of fatty acid methyl esters from hydroxylated vegetable oils on diesel fuel lubricity. *Bioresource Technology*. 2005. Vol. 96. Issue 7. P. 851-855. DOI: https://doi.org/10.1016/j.biortech.2004.07.006

5. Mei D., Luo Y., Shen X., Lu D., Yuan Y. Lubrication properties of fatty acid methyl esters as low-sulfur diesel enhancers. *Transactions of the Chinese Society of Agricultural Engineering*. 2016. Vol. 32, Issue 9. P. 193-197. DOI: https://doi.org/10.11975/j.issn.1002-6819.2016.09.027

6. Mujtaba M. A., Liaquat A. M., Kalam M. A., Masjuki H. H., Varman M., Gulzar M., Shahir S. A. Effect of Additivized Biodiesel Blends on Diesel Engine Performance, Emission, Tribological Characteristics, and Lubricant Tribology. *Energies*. 2020. Vol. 13. Issue 13. DOI: https://doi.org/10.3390/en13133375

7. Geller D. A., Goodrum J. W. Effects of specific fatty acid methyl esters on diesel fuel lubricity. Fuel. 2004. Vol. 83. Issue 17-18. P. 2351-2356. https://doi.org/10.1016/j.fuel.2004.06.004

8. Dr. Venkata Sundar Rao K., Dr. Shreeprakash B., "Effect of Different Biodiesel blends (80% Diesel + 20% Biodiesel) on Tribological Property of I.C. Engine Components", *SSRG International Journal of Mechanical Engineering*, vol. 7, no. 10, pp. 7-10, 2020. *Crossref*, https://doi.org/10.14445/23488360/IJME-V7I10P102

9. Kinoshita E., Ito T., Nakatani N., Uchino M., Yamashita K. The Effect on Diesel Injector Wear, and Exhaust Emissions by Using Biodiesel Fuel. *Materials Transactions*. 2015. Vol. 56. Issue 5. P. 642–647. DOI: https://doi.org/10.2320/matertrans.M2014410

10. Makareviciene V., Janulis P. Environmental effect of rapeseed oil ethyl ester. Renewable Energy, 2003. Vol. 28, Issue 15. P. 2395–2403. DOI: https://doi.org/10.1016/S0960-1481(03)00142-3

11. Singh, P., Sharma, S., Kumar, S. (2022). Impact of Biodiesel Blended Fuels on Combustion Engines in Long Term. In: Kumar, V., Agarwal, A.K., Jena, A., Upadhyay, R.K. (eds) Advances in Engine Tribology. Energy, Environment, and Sustainability. Springer, Singapore. https://doi.org/10.1007/978-981-16-8337-4_3

12. El-Fakharany M. K., Abdelrazek A. S., Baz F. B., Gad M. S. Impact of Nano-TiO_2 Combination with Biodiesel on Diesel Engine Performance and Emissions Under Fuel Magnetism Conditioning. *Arab Journal of Science and Engineering*, 2024. PP.1-16. DOI: https://doi.org/10.1007/s13369-024-09643-w

13. Verma ML, Dhanya BS, Wang B, Thakur M, Rani V, Kushwaha R. Bio-Nanoparticles Mediated Transesterification of Algal Biomass for Biodiesel Production. Sustainability, 2024. Vol. 16(1):295. DOI: https://doi.org/10.3390/su16010295

14. Wenchao W., Fashe L., Ying L. Effect of Biodiesel Ester Structure Optimization on Low Temperature Performance and Oxidation Stability. *Journal of Materials Research and Materials*. 2020. Vol. 9. Issue 3. P. 2727-2736. DOI: https://doi.org/10.1016/j.jmrt.2020.01.005

15. Mythili, R., Venkatachalam, P., Subramanian, P., & Uma, D. (2014). Production characterization and efficiency of biodiesel: a review. International Journal of Energy Research, 38, P. 1233 – 1259. DOI: https://doi.org/10.1002/er.3165

16. Ramar K., Subbiah G. A study of magnetic field influence on performance and emission using biodiesel in DI diesel engine. *AIP Conference Proceedings*, 2024. №3192(1). P.020082. DOI: https://doi.org/10.1063/5.0241518

17. Peng D.X. The Effect on Diesel Injector Wear, and Exhaust Emissions by Using Ultralow Sulphur Diesel Blending with Biofuels. Materials Transactions, 2015. Vol. 56. Issue 5. PP.642-647. DOI: https://doi.org/10.2320/matertrans.M2014410

18. Singapore's maritime decarbonisation centre completes its final marine biofuels trial. *Reuters Sustainability Reports*. 2024. № 7. (date of access: https://www.reuters.com/sustainability/climate-energy/singapores-maritime-decarbonisation-centre-completes-its-final-marine-biofuels-2024-07-19/)

19. Hanaki, K., Portugal-Pereira, J. (2018). The Effect of Biofuel Production on Greenhouse Gas Emission Reductions. In: Takeuchi, K., Shiroyama, H., Saito, O., Matsuura, M. (eds) Biofuels and Sustainability. Science for Sustainable Societies. Springer, Tokyo. https://doi.org/10.1007/978-4-431-54895-9_6

20. Biofuels & Greenhouse Gas Emissions: Myths versus Facts. *Department of Energy Resources Studies*. 2023. № 3. (date of access: https://www.energy.gov/articles/biofuels-greenhouse-gas-emissions-myths-versus-facts-0)