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The issues of using synthetic fuel in diesel transportation

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Abstract: In today's increasingly globalized world, transportation plays a vital role for humanity. As a result, continuous investments are being made in vehicles and their energy sources. Various types of energy sources are used for transportation. For modern vehicles, fuel efficiency and environmental sustainability are considered highly important factors. As alternatives to conventional motor fuels derived from petroleum products, synthetic fuels—such as Fischer-Tropsch fuel, biodiesel, synthetic diesel, and others—are being developed globally. Each developed product is used as an alternative due to its specific economic and environmental advantages. Among alternative fuels, synthetic fuels deserve special mention, as they stand out for their superior environmental performance compared to other types. This article analyzes the main characteristics of using synthetic fuels in diesel vehicles and highlights their advantages over traditional fuels. Scientific research on the use of synthetic fuels in the transportation and energy sectors has been reviewed, and relevant proposals and conclusions have been drawn.

Keywords: synthetic fuel, diesel fuel, crankcase oil, environmental cleanliness, combustion efficiency, energy independence

1. Introduction

It is stated that the total identified amount of the world's oil reserves is half a trillion tons. Of this, 121 billion tons are being extracted from the Earth's crust, 160 billion tons have been identified, and 205 billion tons need to be identified. In our rapidly developing world, the role of transportation in increasing human comfort is significant. Currently, transport is a key locomotive of the economy and one of the main energy consumers. In modern society, it has become clear and evident that humans are having various negative impacts on nature in pursuit of their interests. Given these factors, it is becoming increasingly important to focus on several key aspects in every field, such as ensuring safety, high energy efficiency, minimal environmental harm, and high economic efficiency.

In accordance with the decision of the Cabinet of Ministers of the Republic of Uzbekistan on November 23, 2017, a general technical regulation was established regarding the requirements for diesel and marine fuel, aviation and automobile fuel, jet engine fuel, and fuel oil. This regulation ensures the safety of automobiles and aviation, monitors the delivery of quality fuel to consumers, and aims to reduce the harmful impact of fuels in accordance with ecological standards.

Considering the country's existing gas reserves, the Republic of Uzbekistan, with the goal of producing environmentally friendly synthetic liquid fuels from natural gas and replacing imports to increase export potential, established the "Uzbekistan GTL" LLC enterprise under the decree of the President of the Republic of Uzbekistan in 2009. On December 25, 2021, the opening ceremony of the "Uzbekistan GTL" plant took place. The total area of the plant is 135 hectares, and it produces four types of fuel (aviation kerosene, compressed gas, diesel, and oil). "Uzbekistan GTL" is one of the five largest plants in the world (the other four are located in Qatar, Nigeria, South Africa, and Malaysia).

According to the decree of the President of the Republic of Uzbekistan, PQ-436, on measures to increase the effectiveness of reforms aimed at the transition to a "green" economy in Uzbekistan by 2030, Uzbekistan made a statement during the 26th session of the United Nations Framework Convention on Climate Change (COP26) in November 2021. Uzbekistan has undertaken an additional commitment under the Paris Agreement to reduce greenhouse gas emissions by 35% by 2030 compared to 2010 levels.

2. Literature review and methodology

The trend of using alternative fuels is steadily increasing worldwide. The main reason for this is the limited nature of oil reserves. One of these alternative fuels is synthetic fuel. The literature review analyzes the wide possibilities of using synthetic fuels, the results of comparing them with traditional diesel fuels, and their ecological advantages [8]. The use of various motor fuels, such as hydrocarbon gases, biofuels, and synthetic fuels in transport vehicles, requires appropriate evaluation. Typically, fuel efficiency and environmental impact depend on the acceleration speed of the vehicles, and the operating characteristics of the engine fuel used [24]. The global development of synthetic diesel production based on GTL technology, the chemical processes applied to natural gas, and the use of synthetic diesel fuel in transport vehicles, along with its ecological effectiveness, are discussed [9].

Advanced technologies for producing synthetic fuels using renewable ocean hydro-energy are discussed [10]. The combustion characteristics of synthetic gas, the production process, and technological aspects are reviewed [11]. The differences between synthetic fuels and conventional oil fuels, production efficiency, and price-related factors are analyzed [12].

The production and supply of synthetic kerosene and bio-kerosene in aviation have been thoroughly studied [13]. The technologies for producing liquid GTL fuel through Fischer-Tropsch synthesis and their effectiveness are

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examined [14]. Additionally, the impact of biodiesel on existing pipelines and storage tanks, as well as its quality characteristics in terms of cetane number, are evaluated [15, 16]. The technology and concept of producing biofuels for the transport sector are discussed [17]. The ecological and economic advantages of fuels derived from biomass are mentioned [18].

The production and purification technologies of gaseous fuels, along with the impact of bioethanol on the transport system, and the ecological efficiency of alternative fuels, have been studied and justified [23, 24, 25]. Research focusing on analyzing the quality indicators of diesel fuel and improving its ecological safety has been conducted [26]. The composition and ecological indicators of a mixture of synthetic and conventional diesel are evaluated [27].

Moreover, studies on the addition of depressant additives to increase the seasonal adaptability of diesel fuel are also discussed [28]. The impact of alternative fuel types on vehicles and their ecological aspects is examined [29, 30, 31].

The Uzbekistan National Standard 989:2010 – "Diesel Fuel: Technical Specifications" outlines the safety requirements, quality standards, and testing methods for diesel fuel derived from the refining of oil and gas. [34].

The Uzbekistan National Standard 12.1.044–2018 – "Occupational Safety Standards System. Fire and Explosion Hazard of Substances and Materials. Nomenclature of Indicators and Methods for Their Determination" sets out the methods for determining the explosion hazard indicators of substances and materials. [35].

Alternative fuels are a competitor to traditional motor fuels due to their energy and ecological indicators [7]. The development and use of synthetic fuels have been increasing year by year. For instance, the Uzbekistan GTL plant processes 3.6 billion cubic meters of natural gas annually, producing 1.5 million tons of finished liquid products. This includes 307 thousand tons of synthetic aviation kerosene, 724 thousand tons of diesel fuel, 437 thousand tons of oil, and 53 thousand tons of liquefied gas. The plant produces synthetic aviation kerosene and Euro-6 (YEN15940) European ecological standard-compliant synthetic diesel fuel of the "premium-class" category, fully meeting the international standard (ASTM D-7566) and technical requirements [33, 36].

To assess the advantages of synthetic fuels, the methodologies used in the literature include the following:

- **Comparative Analysis** – Comparing the physical and chemical properties of traditional and synthetic fuels [8, 12, 27].
- **Experimental Analysis** – Analysis of diesel fuel produced by synthetic liquid fuel production technology under laboratory conditions [9, 14].
- **Ecological Evaluation** – Studying the amount of harmful emissions resulting from the combustion of fuel and its environmental impact [10, 18, 31].
- **Technological Process Analysis** – Reviewing the stages of synthetic fuel production, economic, and efficiency indicators [11, 14, 17].
- **Aviation and Transport Applications** – Studying the use of synthetic and biofuels in commercial transport [13, 16, 25].

Advantages and Disadvantages of the Methods Used:

- **Comparative Analysis** – This method involves comparing two or more processes or objects based on a specific criterion. The advantage of this method is that the researcher can clearly identify the strengths and weaknesses of each object, making it easier to choose the most economically efficient option. However, this method has some drawbacks. The objects being compared may be conducted under different conditions, which can lead to various errors.
- **Experimental Analysis** – This method involves testing a theoretical hypothesis through practical experiments, analyzing the results, and drawing conclusions. It is the most effective method for confirming or refuting theoretical assumptions. Its disadvantage is that it often requires significant time, specialized equipment, and increased financial costs.

Technological Process Analysis – This method analyzes the technological processes in production or technical systems, studying their energy efficiency, economic costs, and resource consumption to achieve optimal results. The advantage of this method is that it helps identify weak and resource-intensive stages, showing where faults may occur and aiding in process optimization. However, analyzing all stages of processes in complex systems requires considerable time and expertise. It is not always possible to achieve results through simple observation, and complex algorithms and modeling may be required, which can be a drawback.

3. Research results and Discussion

The presence of sulfur compounds in fuel is undesirable because they combine with water during the combustion process, releasing gases that form highly reactive acids. This leads to rapid corrosion of engine parts. For instance, when 1 ton of fuel containing 1% sulfur burns, it generates 20 kg of sulfuric acid. As a result, the wear and tear on engine parts when using such fuel (compared to fuel with 0.2% sulfur) increases 2-3 times [6]. In contrast to conventional diesel fuels, synthetic fuels contain very low levels of sulfur (as shown in Table 1), which reduces harmful gas emissions into the atmosphere and minimizes the corrosion of engine parts [20].

When using traditional diesel fuel with a high acid content, the efficiency of the injectors decreases by 7 times, and the wear of the plunger pairs and compressor rings increases by 2 times. Therefore, technical specifications prohibit the acid number of diesel fuel from exceeding 5 mg KOH/100 cm^3 [22]. For synthetic diesel fuel, this indicator is typically 0.01 mg KOH/100 cm^3.

Synthetic fuels emit significantly fewer carbon emissions into the environment compared to traditional diesel fuels [6]. Specifically, synthetic fuels produce fewer NO_X and CO_2 emissions due to their clean combustion properties, thus reducing the release of pollutants into the atmosphere [9,19].

The synthetic diesel fuel obtained has superior characteristics compared to diesel fuel derived from oil fractions (which comply with European standard EN-590):

- Cetane number: greater than 75, compared to 55 for traditional diesel fuel;

- Polar aromatic hydrocarbons content: 0.1%, compared to 6% in traditional diesel fuel;
- Sulfur content: 0 ppm, compared to 500 ppm in traditional diesel fuel;
- Density: 767 kg/m³, compared to 835 kg/m³ in traditional diesel fuel.

Table 1

Characteristics of Conventional, Biodiesel, and Synthetic Diesel Fuels

Characteristic	Conventional diesel	Biodiesel (B100)	Synthetic diesel
Volatility	Evaporates moderately slowly	Very low, almost non-evaporating	Medium or low, close to conventional diesel
Vapor pressure kPa (At 38 °C)	0.4-0.7	Very low (almost none)	0.3-0.6
Fire temperature (At °C)	52-96	130-170	65-100
Autoignition temperature (At °C)	~210	~250	~230
Evaporation rate	It evaporates slowly.	It evaporates very slowly.	Evaporates slowly but steadily
Flammability	Produces steam at moderate, low temperatures	Less flammable, does not produce vapors	Good low temperature flammability
Cleanliness and ecology	Rich in sulfur, high in NOx and PM emissions	Clean burning, low harmful emissions	Clean burning, low NOx and PM emissions

Due to its high combustion efficiency, synthetic fuel burns more completely compared to conventional diesel, which improves engine performance. Synthetic fuels leave less residue, thus slowing down the wear process of the engine. Synthetic fuels can be used either mixed with conventional diesel or on their own. Due to their clean composition, synthetic diesel fuel is heat-resistant and maintains good combustion properties even in cold weather. The minimal sulfur content reduces harmful gas emissions to the environment.

Synthetic fuels, when used in diesel vehicles, provide both ecological sustainability and energy efficiency. They allow the vehicle to be operated without any modifications to the engine under normal operating conditions. In the future, the use of this type of synthetic fuel can reduce dependency on oil while achieving high ecological performance.

4. Conclusion

In conclusion, the scientific research conducted by scholars on synthetic diesel fuel is crucial for energy, transport, and environmental concerns. Using synthetic diesel can improve the efficiency of a transport vehicle by up to 4-7%. The use of this type of fuel also requires less maintenance for filters, injectors, and catalysts, contributing to economic efficiency. Research conducted by SAE International has shown that Fischer - Tropsch (FT) synthetic diesel fuel reduces sediment waste by up to 52% compared to conventional diesel. The lower amount of sediment generated helps prolong the lifespan of injectors and the EGR system, while also reducing nitrogen oxide emissions to the atmosphere. However, the impact of synthetic fuels on engine crankcase oil has not been sufficiently studied in transport vehicles. Due to the low sulfur and harmful substances content in synthetic diesel, it ensures better engine performance. The impact of synthetic diesel on the lifespan and quality of crankcase oil during operation remains underexplored. In this regard, scientific research should be conducted to identify the issues and develop technical solutions.

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