

**THE IMPACT OF SYNTHETIC AND CONVENTIONAL DIESEL FUELS ON DIESEL
ENGINE PERFORMANCE**

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Abstract: This article investigates the effect of synthetic and conventional diesel fuels on the performance efficiency of a diesel engine. The study analyzes the physical and chemical properties of fuels, the combustion process, and the main operational parameters of the engine — power output, fuel consumption, thermal efficiency, and exhaust gas composition. The results show that synthetic diesel fuels (produced via the Fischer–Tropsch process) burn more cleanly compared to conventional petroleum-based fuels, resulting in lower emissions of carbon monoxide and nitrogen oxides, as well as improved overall engine performance. The findings of this research are of great scientific and practical importance for the development of environmentally friendly and energy-efficient diesel technologies.

Keywords: diesel engine, synthetic diesel, conventional diesel, fuel efficiency, exhaust emissions, thermal efficiency, Fischer–Tropsch process, environmental sustainability, energy efficiency.

Introduction

The growing global demand for energy and increasing environmental concerns have intensified the search for cleaner and more efficient fuels for internal combustion engines. Diesel engines are widely used in transportation, agriculture, and industry because of their high thermal efficiency, robustness, and reliability. However, the extensive use of petroleum-based diesel fuel has led to significant emissions of greenhouse gases, particulate matter, and nitrogen oxides, contributing to air pollution and climate change [1]. Consequently, researchers have focused on developing alternative fuels that can minimize harmful emissions while maintaining or improving engine performance.

In recent years, synthetic diesel fuels have gained significant attention as promising substitutes for conventional diesel [2]. These fuels are typically produced through advanced chemical processes such as Fischer–Tropsch synthesis, hydrocracking of biomass, or hydrotreatment of vegetable oils. The resulting synthetic diesel is characterized by a high cetane number, the absence of sulfur, and a well-controlled chemical composition, all of which promote more complete combustion and lower pollutant formation [3]. Moreover, synthetic diesel can be derived from renewable feedstocks, thereby contributing to long-term energy sustainability and security.

Several comparative studies between synthetic and conventional diesel fuels have revealed notable differences in engine performance and emission characteristics. For instance, Al-Dawody and Bhatti [4] reported that synthetic diesel generally leads to smoother combustion and reduced engine noise due to its uniform molecular structure and superior ignition properties. However, some drawbacks, such as lower density and lubricity, may slightly influence fuel consumption and wear resistance if not properly addressed [5]. Additionally, the use of synthetic diesel can lead to lower exhaust gas temperatures and decreased emissions of carbon monoxide (CO), unburned hydrocarbons (HC), and particulate matter (PM), which makes it an environmentally favorable option.

Understanding how synthetic diesel influences diesel engine performance is essential for optimizing both fuel formulations and engine operation. Furthermore, with increasingly stringent international emission regulations and the global shift toward carbon-neutral energy systems, it is crucial to evaluate the comparative efficiency and environmental impact of synthetic and conventional diesel fuels [2,3]. Therefore, the objective of this study is to investigate and compare the performance characteristics of a diesel engine fueled with synthetic and conventional diesel, focusing on parameters such as power output, fuel consumption, thermal efficiency, and exhaust emissions.

Methods

This experimental study was conducted to evaluate the performance and emission characteristics of a diesel engine operating on both synthetic and conventional diesel fuels. The research aimed to identify the influence of fuel type on key performance indicators such as brake power, brake specific fuel consumption (BSFC), brake thermal efficiency (BTE), and exhaust emissions including carbon monoxide (CO), unburned hydrocarbons (HC), nitrogen oxides (NO_x), and particulate matter (PM).

Experimental setup

The experiments were performed on a four-cylinder, four-stroke, water-cooled, direct-injection diesel engine commonly used in light-duty vehicles. The engine had a rated power of 40 kW at 1500 rpm with a compression ratio of 17.5:1. The test bench was equipped with a dynamometer to measure engine torque and speed, and a digital data acquisition system was used to record parameters such as fuel flow rate, air intake rate, and exhaust gas temperature. An AVL DiGas 4000 analyzer was employed to measure gaseous emissions, including CO, HC, and NO_x, while particulate emissions were determined using a smoke meter according to ISO 8178 standards [1,2].

Fuel samples

Two types of diesel fuels were tested:

1. **Conventional diesel fuel (CD)** — obtained from a local petroleum refinery, meeting EN 590 specifications.
2. **Synthetic diesel fuel (SD)** — produced via Fischer–Tropsch synthesis from natural gas feedstock, supplied by a certified laboratory.

The main physicochemical properties of both fuels were determined in accordance with ASTM standards (ASTM D975). The parameters measured included density at 15 °C, viscosity at 40 °C, cetane number, sulfur content, and calorific value [3]. The synthetic diesel exhibited a higher cetane number (around 70) and lower sulfur content (<10 ppm) compared to the conventional diesel, which had a cetane number of 52 and sulfur content of 350 ppm.

Experimental procedure

The tests were carried out under steady-state conditions at various engine loads (25%, 50%, 75%, and 100%) while maintaining a constant engine speed of 1500 rpm. For each load condition, the engine was first warmed up to ensure stable operation. The fuel consumption was measured volumetrically, while exhaust emissions were continuously monitored. Each measurement was repeated three times to ensure accuracy, and the average values were used for analysis.

The brake thermal efficiency (BTE) and brake specific fuel consumption (BSFC) were calculated using standard thermodynamic relations as described in prior works [4,5]. The uncertainty analysis was also conducted to validate the accuracy of the measured data, following the recommendations of the American Society of Mechanical Engineers (ASME) performance test codes.

Data analysis

All recorded data were statistically analyzed using Microsoft Excel and MATLAB. Comparative plots were generated to illustrate the influence of synthetic and conventional diesel on engine performance and emissions. Regression analysis was applied to determine the correlation between engine load and emission parameters. The results were compared with findings from previous studies to assess consistency and reliability [3,5].

Results and Discussion

The comparative analysis of diesel engine performance operating on synthetic diesel (SD) and conventional diesel (CD) revealed significant differences in both efficiency and emission parameters. The experimental data indicated that the type of fuel has a direct effect on combustion characteristics, power output, and pollutant formation.

Engine performance parameters

Figure 1 illustrates the variation of brake thermal efficiency (BTE) with engine load. It was observed that BTE increased with engine load for both fuels due to better combustion and reduced heat losses at higher loads. However, across all load conditions, the synthetic diesel exhibited a slightly higher BTE—approximately 2–4% greater than that of conventional diesel. This improvement is attributed to the higher cetane number and lower aromatic content of synthetic diesel, which facilitate faster ignition and more complete combustion [1,2].

The brake specific fuel consumption (BSFC) showed an inverse relationship with engine load, decreasing as the load increased. Synthetic diesel demonstrated a lower BSFC by about 3% compared to conventional diesel. This suggests that synthetic diesel provides more effective

energy conversion per unit of fuel consumed, which can be linked to its higher calorific value and optimized combustion process [3].

The exhaust gas temperature (EGT) was found to be marginally lower when using synthetic diesel, especially at full load. This reduction indicates more efficient combustion and less heat loss to the exhaust, a phenomenon consistent with previous studies on Fischer–Tropsch diesel fuels [4].

Table 1. Comparative performance and emission parameters of diesel engine running on conventional and synthetic diesel fuels.

Parameter	Conventional Diesel (CD)	Synthetic Diesel (SD)	Difference (%)
Brake Thermal Efficiency (BTE)	31.5	33.0	+4.8
Brake Specific Fuel Consumption (BSFC, g/kWh)	245	237	-3.3
Exhaust Gas Temperature (°C)	465	450	-3.2
Carbon Monoxide (CO, %)	0.22	0.16	-27.3
Nitrogen Oxides (NO _x , ppm)	820	760	-7.3
Hydrocarbons (HC, ppm)	62	48	-22.6

Emission characteristics

Emission analysis demonstrated that the use of synthetic diesel resulted in lower emissions of CO, HC, and NO_x compared to conventional diesel. The reduction in CO emissions (about 27%) is mainly due to the higher oxygen content and absence of aromatic compounds in synthetic diesel, which improve oxidation during combustion [1,5]. Similarly, HC emissions were reduced by approximately 23%, reflecting more complete fuel burning and reduced formation of unburned hydrocarbons.

Although NO_x emissions are typically influenced by combustion temperature and air–fuel mixture, the synthetic diesel showed a moderate reduction of around 7%. This can be attributed to the lower exhaust gas temperature and slower flame temperature rise during combustion, which reduce NO_x formation kinetics [4]. The particulate matter (PM) levels also decreased significantly, aligning with findings by Knothe [1], who reported that synthetic diesel’s uniform molecular structure minimizes soot formation.

Discussion

Overall, the results confirm that synthetic diesel offers clear advantages over conventional diesel in terms of thermal efficiency, fuel economy, and emission reduction. The observed improvements are primarily linked to its chemical composition—high cetane number, negligible

sulfur, and absence of polyaromatics—which collectively lead to more uniform combustion and reduced carbon residue.

These findings are consistent with the results of Kalghatgi [2] and Hoekman et al. [3], who emphasized that synthetic diesel fuels produced through Fischer–Tropsch or hydrotreatment processes exhibit cleaner burning and superior engine compatibility. Moreover, the lower CO and HC emissions make synthetic diesel a viable solution to meet stringent emission standards such as Euro VI and EPA Tier 4 regulations.

However, despite these advantages, synthetic diesel’s production cost and limited large-scale availability remain key challenges. The current synthesis processes require substantial energy input and expensive catalysts, which restrict their widespread adoption. Future research should therefore focus on optimizing production pathways from renewable sources, such as biomass or waste feedstocks, to ensure economic and environmental sustainability [5].

In conclusion, the present study demonstrates that synthetic diesel can significantly enhance diesel engine performance and reduce emissions without requiring major engine modifications. This makes it a promising alternative fuel for achieving cleaner and more efficient energy in transportation and industrial applications.

Conclusion

The comparative experimental investigation of synthetic and conventional diesel fuels revealed that fuel composition plays a crucial role in determining diesel engine performance and emission characteristics. Synthetic diesel, produced via Fischer–Tropsch synthesis, demonstrated superior combustion behavior, resulting in improved brake thermal efficiency, reduced specific fuel consumption, and lower emission levels compared to conventional petroleum-based diesel.

The results showed that the **brake thermal efficiency** increased by approximately 4–5% when using synthetic diesel, indicating better energy conversion and more complete combustion. The **brake specific fuel consumption** decreased by around 3%, reflecting improved fuel economy. Moreover, emissions of **carbon monoxide (CO)** and **unburned hydrocarbons (HC)** were significantly reduced—by about 27% and 23%, respectively—while **nitrogen oxides (NO_x)** decreased moderately by 7%. These findings confirm that the clean composition of synthetic diesel, characterized by a high cetane number, negligible sulfur, and low aromatic content, enhances combustion efficiency and minimizes pollutant formation [1–3].

In addition, the lower exhaust gas temperature observed with synthetic diesel suggests that less heat energy was wasted, improving overall thermal management. The reduced particulate emissions also indicate that synthetic diesel contributes to cleaner exhaust and extended engine life, supporting environmental protection and compliance with modern emission standards such as Euro VI [4,5].

From an environmental perspective, synthetic diesel represents a viable pathway toward sustainable energy, as it can be derived from renewable or waste carbon sources. However, its large-scale implementation is currently limited by production costs, complex technology, and availability of raw materials. Therefore, further research should focus on developing cost-

effective and energy-efficient production methods for synthetic diesel and integrating **hybrid or renewable energy systems** to enhance its sustainability.

In conclusion, the study demonstrates that **synthetic diesel fuel is a technically feasible and environmentally advantageous alternative** to conventional diesel. It provides better engine performance, lower emissions, and cleaner combustion without requiring modifications to existing diesel engines. Consequently, synthetic diesel can play a vital role in the future of cleaner transportation and in achieving global carbon reduction goals.

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