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EFFECT OF ETHANOL BLEND ON THE ENGINE CHARACTERISTICS BASED ON SIMULATION METHOD

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ABSTRACT

Currently, fossil fuel exhaust and the polluted environment are the challenges worldwide; there are many methods, such as using electric vehicles, alternative fuels like solar energy and CNG, or changing the fuel composition like E5, E10 gasoline, etc. However, there is still a lack of documentation related to the impact of fuel composition on engines at different speed ranges. Therefore, this paper uses AVL-Cruise software to simulate an engine operating at various speed ranges from 1800 to 3000 rpm, adding different fuel injections alongside Diesel fuel. The advantages of using new fuels in Diesel engines can be partially assessed based on the simulation results such as power, fuel consumption rate, and engine characteristics when additional fuels are injected to alter the fuel composition.

1. INTRODUCTION

Energy is the foundation of the economy and of economic development. Most of the world's energy needs are currently met by fossil fuels (Abas et al., 2015). However, the technology of fossil fuel extraction, transportation, processing, and especially final use (combustion) has environmentally harmful impacts, causing both direct and indirect negative effects on the economy (Dincer, 1998). Coal mining damages land that needs to be mined and restored for use over several years. During the extraction, transportation, and storage of oil and gas, spills and leaks occur, causing water and air pollution (Worlanyo & Jiangfeng, 2021). Refining processes also have environmental impacts. However, most of the environmental impacts of fossil fuels occur during their final use. The ultimate purpose of using all fossil fuels is combustion (Barbir et al., 1990).
The transition to clean and sustainable energy is happening rapidly, with global policies aimed at reducing greenhouse gas emissions and increasing the use of renewable energy (Yuksel & Kaygusuz, 2011). The future of energy will depend on balancing global energy needs with environmental protection.

Typically, alternative fuels can be used in engines either in pure form (100% alternative fuel) or blended, meaning a portion of alternative fuel combined with traditional fuel (Bae & Kim 2017). Examples include the B5 fuel blend (5% bio-diesel, 95% traditional diesel) and the E5 fuel blend (5% ethanol, 95% gasoline). (Elgohary et al., 2015, Zhou et al., 2017; Noor et al., 2018, Wang et al., 2020).
Fuel composition greatly affects the performance, lifespan, and reliability of engines (Schäfer et al., 2006). Choosing the right fuel with an appropriate octane or cetane rating, high energy content, low impurities, and high-quality additives can optimize engine operation, improve efficiency, and reduce maintenance costs. A deep understanding of these factors is important to ensure efficient and durable engine operation.
Throughout history, liquid hydrocarbon fuels for transportation and aviation applications have been refined from crude oil recovered from beneath the Earth's surface. Hydrocarbons are compounds containing only hydrogen and carbon elements (Hsu, 2010). A compound is defined as a pure chemical substance consisting of two or more elements bonded in a specific arrangement and exhibiting a fixed ratio of different elements. The term "petroleum" originates from the Latin root, its literal

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translation being "rock oil." As traditional petroleum supply has been consumed, the cost of oil production has increased, and concerns about environmental and political issues related to petroleum use have grown (Murphy, 2014)

Studies have shown that the E10 alternative fuel system may not be of concern for the erosion of metal components, and E20 does not have much impact on operation (Linzenich et al., 2019). However, the plastic components of older engines will be affected (Lee, 2014; Minteer, 2016).

In this article, to understand the impact of fuel composition on engines, we use AVL Cruise software: "***Investigating the Impact of Fuel Composition on Engine using AVL Cruise software***," simulating a 6-cylinder engine using two fuel injectors directly in the diesel combustion chamber and a secondary injector on the intake manifold for methane, hydrogen, and butane-propane-ethane fuels.

2. SIMULATION

2.1. Simulation Software

In this study, we utilized AVL Cruise software Boost, version from 2009 for simulation purposes.

Introduction to the Vibe Combustion Model

The Vibe combustion model was developed to simulate the heat release process in internal combustion engines. This model is favored due to its simplicity and ability to provide the necessary parameters for engine performance analysis.

Vibe Model Formula

The Vibe model is based on a mathematical equation to describe the development of the combustion process, represented as follows:

$$x(\theta) = 1 - exp\left[-a(\frac{\theta - \theta_s}{\Delta\theta})^{m+1}\right]$$

Where:

x(θ) is the fraction of heat released up to the crank angle θ.

θ is the crankshaft angle

θ_s is the start of the combustion angle

$\Delta\theta$ is the duration of combustion (crank angle)

a and m are tuning constants to fit experimental data

Tuning Parameters in the Vibe Model

Constant a: Determines the rate of heat release. The value of a affects the slope of the combustion curve.

Constant m: Determines the shape of the combustion curve, with different values producing different heat release patterns.

2.2. Engine Simulation

Based on a real engine and using the elements available in AVL Boost, the technical specifications of the engine (Table 1) were used to construct the engine model as shown in Figure 1.

Table 1: Engine Specifications

Engine Type	6-cylinder Turbocharged Diesel Engine Piston
Stroke	130mm
Compression Ratio	18:1
Bore	100mm
Conrod Length	220mm
Fuel System	Direct Injection Diesel Fuel
	Alternative Fuels: Injected via intake manifold

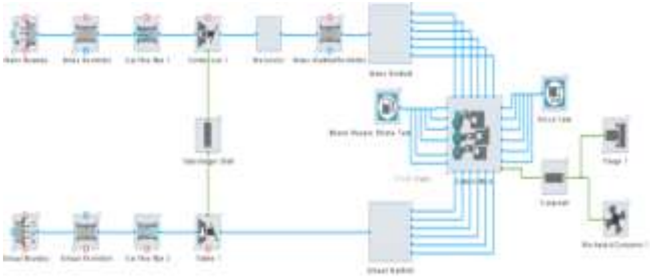

Figure1. Simulation Model

2.3. Simulation Execution

In this study, simulations were conducted at a compression ratio of 18, with the throttle fully open. The engine speed varied from n = 1800 to 3000 rpm, with n = 200 rpm increments.

To evaluate the impact of fuel composition on the engine, this study focused on understanding the factors of power, torque, fuel efficiency, highest heat release rate, highest cylinder temperature, and pressure. We varied the amount of the second fuel injection, in addition to the primary fuel, which is Diesel, to include Methane, Hydrogen, and Butane_propane_ethane (0.5:0.4:0.1) with m = 0 mg corresponding to m_methane = 0 mg, m_hydrogen = 0 mg, and m_butane_propane_ethane = 0 mg. Similarly, in case 2: m = 5 mg, we have m_methane = 5 mg, m_hydrogen = 5 mg, and m_butane_propane_ethane = 5 mg, where each compound is in the ratio (0.5:0.4:0.1). In this study, we used m = 0, 5, 10, 15, 20 mg to investigate these factors.

3. SIMULATION RESULTS

Figure 2 shows the engine efficiency in all 5 cases tends to increase as the total fuel quantity injected into the engine increases. For each case, at m = 0 mg, the efficiency is the lowest compared to all other cases, and the highest efficiency is achieved when fuel is injected at m = 20 mg. The minimum efficiency difference at 180 rpm is 52 kW, and the maximum difference at 3000 rpm is 78 kW. This diagram shows that this dual-fuel engine adequately meets the requirements when using alternative fuels instead of traditional fuel (Figure 3).

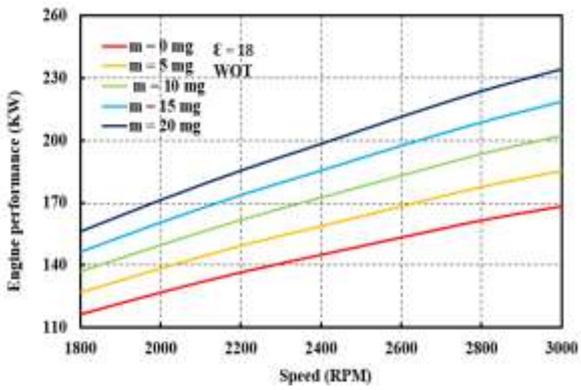

Figure 2. Engine Efficiency with Dual-Fuel Injection

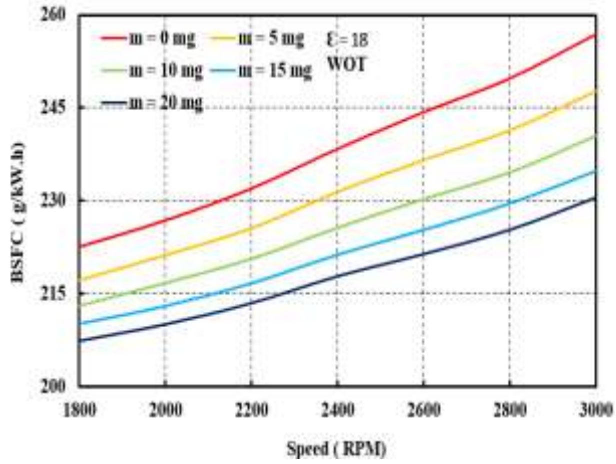

Figure 3. Engine Fuel Consumption Rate with Speed

As efficiency increases, the engine can convert more energy from fuel into useful work, producing less fuel needed to produce a certain power output. This decreases the BSFC. Conversely, if efficiency decreases, the engine requires more fuel to produce the same power output, increasing the BSFC. The fuel consumption rate tends to increase as the engine speed increases. At low speeds, engine efficiency typically decreases due to mechanical losses and suboptimal combustion temperatures, leading to higher BSFC, meaning the engine consumes more fuel to produce the same amount of power. In the tested cases, the BSFC of m20 is the lowest, and m0 is the highest.

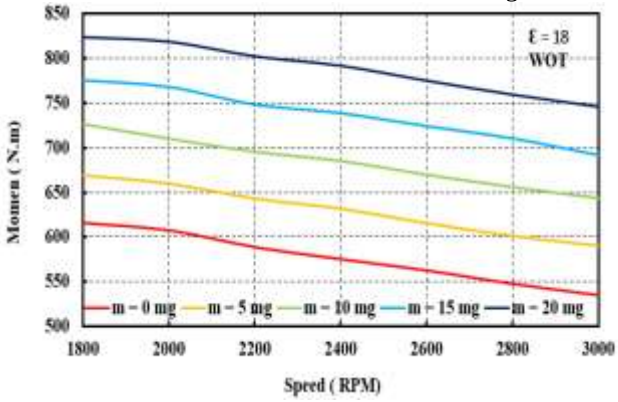

Figure 4. Engine Torque vs. Speed and Fuel Composition

In Figure 4, we observe a decreasing trend in engine torque for all 5 cases, with each case showing a similar decreasing trend. However, the graph shows that m20 has higher torque than m0 at all engine speeds. Thus, when additional fuel is injected into the engine, changing the fuel composition helps optimize thermal energy conversion into mechanical work, enhancing torque.

Figure 5 demonstrates that the maximum heat release rate increases with engine speed changes. However, injecting additional fuel into the engine at different speeds helps increase the heat transfer rate. Here, m20 has the highest heat transfer rate, 1.26 times higher. When additional fuel is injected, several factors contribute to the increased heat transfer rate, such as increased fuel heat content, leading to higher combustion temperatures, stable combustion processes, and cleaner burning fuels that produce less soot and deposits, helping to maintain heat transfer rates.

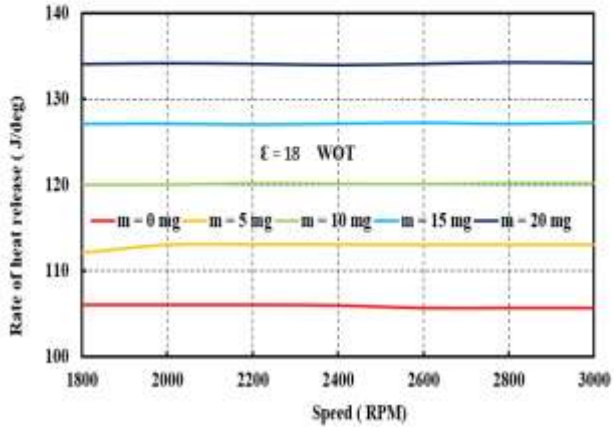

Figure 5. Maximum heat release rate according to engine speed

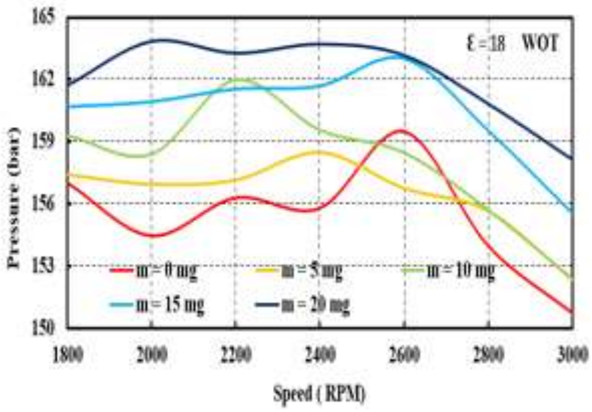

Figure 6. Pressure variation according to fuel composition

Pressure in the cylinder is the main factor affecting engine efficiency. From Figure 1, we can see that Figure 6 shows the engine pressure according to fuel composition and speed. It is correct that m20 is always higher than all other cases.

Figure 7 shows the highest cylinder temperature when the fuel composition is changed. The temperature of the tested cases tends to increase, but the m20 has the highest temperature at all engine speeds. Therefore, we can conclude that injecting additional fuel to change the original diesel fuel composition helps optimize the combustion process, leading to increased temperature.

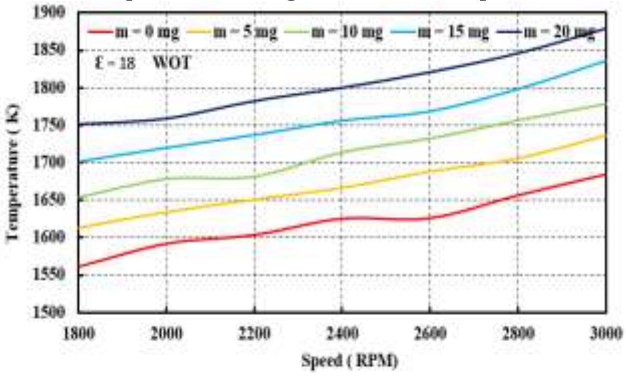

Figure 7. Effect of highest temperature in greens according to raw material composition

4. CONCLUSION

Injecting additional fuel into the engine with each case changes the original fuel composition, improving the combustion process as the engine efficiency increases the most at 300 rpm, reaching 78 kW, while the fuel consumption rate decreases by 1.11 times. This is the basis for studying changes in fuel composition to improve engine performance in the context of increasingly scarce fuel resources.

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