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Practical Experience in Blending Al_2O_3, and Fe_2O_3 with Biodiesel, Long-Chain Alcohol and Fossil Diesel

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ABSTRACT

Diesel is one of the most common fuels which makes us think about how to save that type of fuel some theories are about losing Fossil diesel from the earth if we continue to use more and more. So biodiesel, one of the most prominent alternatives to diesel, is produced from waste cooking oil. It has a higher viscosity than diesel, despite its low cetane number. In the current study, an experimental work was carried out on a single cylinder of direct injection air-cooled diesel engine. A certain proportion of the test blended diesel was prepared of five blends, which are: (a) a mixture which consist of 80% diesel (D) and 20% biodiesel(B), (b) 80% diesel and 10% biodiesel was also dissolved with long-chain alcohol pentanol (P) at a rate of 10%, (c) the third is a mixture was prepared by adding 0.5gmAl_2O_3 to the second mixture of B10P10D80, (d) and 0.5gmFe_2O_3 particles added to B10P10D80, (e) the final blended fuel was compromised of 0.5gmAl_2O_3, 0.5gmFe_2O_3 particles added to B10P10D80. The engine performance and emissions were studied at variable engine loads which are ranged from 0.01 kW to 3.5 kW, and constant speed 3000rpm. The results showed that the brake-specific fuel consumption (BSFC) for the mixtures of B20D80, B10P10D80, B10P10D80+Fe_2O_3, and B10P10D80+Al_2O_3+Fe_2O_3 were increased by 26.08%, 30.4%, 1.3%, and 0.46%, respectively, due to oxygen availability in the composition. While it was found that B10P10D80+Al_2O_3 had a minimum BSFC of about 3.06%. These mixtures enhance the brake thermal efficiency (BTE), gradually. Concerning the emissions compared to diesel fuel (D100), the gases of (NOx), (CO), unburned hydrocarbons (HC), and smoke opacity were decreased.

1. INTRODUCTION

Diesel fuel is used in various sectors, including transportation, agriculture, and industry. In addition to trucks, buses, power plants, and trains, which have significant economic. in this study mix diesel, biodiesel, and long-chain alcohol like pentanol, with two types of nano article I mentioned in the research summary and this study that we are about to test the mentioned mixtures on Iraqi diesel [1]. While this is true, diesel combustion still impacts the environment significantly. The emission of nitrogen oxides (NO_x) and particulate matter from diesel engines contributes to air pollution. Carbon dioxide (CO_2) is also released during the combustion of diesel, which contributes to global warming. A cleaner fuel and tighter emission standards are being developed and adopted to reduce diesel's environmental impact. An important challenge for sustainable development is finding a balance between the economic importance of diesel and the need to address its environmental impacts [2, 3].

Adding biodiesel to diesel fuel can significantly reduce its environmental impact. As a more environmentally friendly alternative to petroleum fuel, biodiesel produced from renewable sources such as plant oils or animal fats emits fewer harmful pollutants. Combining biodiesel with conventional diesel reduces carbon monoxide (CO_2), particulate matter, and hydrocarbon emissions (HC) [4]. Due to this, biodiesel emits less sulfur dioxide (SO_2) than conventional diesel [5]. The use of biodiesel not only improves air quality, but it also reduces greenhouse gas emissions. The incorporation of biodiesel into a fuel mix provides a viable pathway to meet energy needs and minimize the environmental impact associated with diesel use.

Pollutant emissions and engine performance may be improved by diesel fuel that contains long-chain alcohols. Diesel fuel combustion efficiency is enhanced when butanol and pentanol are blended with diesel fuel due to their oxygen-rich molecular structure [6]. By improving combustion, (NO_x) and particulate matter emissions are reduced compared to conventional diesel engines. As a result of adding long-chain alcohols, fuel-air mixtures become more homogeneous, which improves engine performance by reducing incomplete combustion [7]. The higher cetane number of these alcohols can enhance fuel efficiency and smoother engine operation. In addition to providing an environmentally friendly and renewable alternative to fossil fuels, long-chain alcohol additives also reduce dependence on fossil fuels, resulting in the development of more efficient and sustainable diesel engines. Long-chain alcohol additives contribute to cleaner combustion processes and help reduce dependence on fossil fuels [8].

The aim of the current study is to introduce an alternative to conventional Iraqi diesel, which has high sulfur content. The used additives are available in Iraqi markets and the used biodiesel is prepared from waste restaurants oils.

2. LITERATURE REVIEW

By incorporating nanoparticles into diesel fuel, engine performance can be enhanced and emissions can be reduced at the same time [9]. The catalytic properties of nanoparticles, like cerium oxide and iron oxide, improve combustion efficiency when they are added to diesel fuel [10]. These nanoparticles act as catalysts, breaking down hydrocarbons and reducing pollutants like nitrogen oxides (NO_x). As well as improving fuel economy, nanoparticles can reduce carbon dioxide emissions and increase combustion efficiency [11]. The use of nanoparticles contributes to a more complete combustion process in that they optimize engine performance, reduce fuel consumption, and reduce pollution [12]. By improving the efficiency of diesel engines and addressing environmental concerns associated with diesel combustion, a more sustainable and eco-friendly transportation landscape can be achieved.

A high percentage of oxygen is present in additives such as biodiesel and pentanol, which is the basis of the current study. Two types of nanoparticles are also added to stimulate the fuel molecules. Biofuels/diesel blends reduce particulates, unburned hydrocarbons, and carbon monoxide emissions, according to many references, such as the studies [13-16]. A reduction in emissions and an improvement in engine performance can be achieved by adding nanoparticles to diesel fuel to reduce ignition delay and knocking [17]. Adding carbon Nanotubes CNT to diesel results in accelerated evaporation and shortened ignition delay times according to Tyagi et al. [18], Basha and Anand [19]. Adding nanoparticles also improves the thermal conductivity, kinematic viscosity, and flash point of fuel [20, 21]. Based on the results of the studies of Tomar and Kumar [22] and Shekofteh et al. [23], it was found that the addition of alumina nanoparticles and Multi-Walled Carbon Nanotubes MWCNT to diesel and biodiesel blends affected the performance and emissions of diesel engines. In contrast to adding multi-walled carbon nanotubes (MWCNT), alumina was found to show satisfactory results. According to the study of Selvan et al. [24], adding cerium oxide (CeO_2) and CNT nanoparticles to diesel engines while changing the compression ratio (CR) significantly improved engine performance. As a result of combining the two nanoparticles, the authors were able to reduce emissions and achieve a cleaner combustion. An investigation of the performance and emissions of diesel engines using aluminum oxide, CNT, and silicon oxide (SiO_2) additives was conducted by the study of Chen et al. [25]. By adding these additives to combustion, NOx emissions were reduced. A study was conducted [26] to determine how graphite oxide (GO_2) and CNT affect the performance characteristics of a light diesel engine. The use of both nanoparticles is reported to reduce diesel engine emissions.

Adding biodiesel, long-chain alcohol like pentanol, octanol, butanol, or nanoparticles individually to the fuel can improve engine performance and reduce pollutants to some extent, according to previous studies. Despite this, no substantial studies have been done on mixing diesel with the three materials in predetermined proportions. To reduce emissions and improve performance, biodiesel produced from waste oil is mixed with long chain pentanol alcohol, alumina AL_2O_3, and iron oxide Fe_2O_3 nanoparticles in predetermined proportions.

A lot of nanomaterials do not dissolve in diesel fuel, biodiesel, and alcohol, and most of them dissolve in acids, note that acids are undesirable in combustion for their harmful residues in our experiment the nanomaterials were mixed in an ultrasonic mixing device to ensure the attachment of. The selected nanomaterial Al_2O_3 white color and Fe_2O_3 reddish-brown see the Figure 1. Both have the same number of metal and oxygens particles, see the Table 1 (the nano-materials properties).

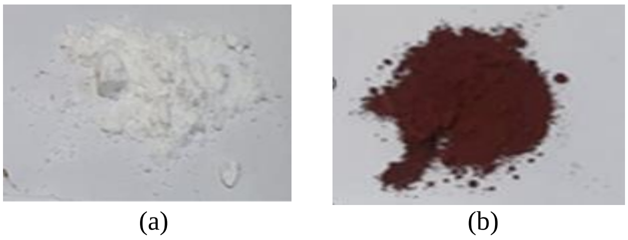
(a) (b)

Figure 1. (a) Nano-Al_2O_3 and (b) Nano-Fe_2O_3

Table 1. The nano alumina and iron oxide properties

Nano-Fe_2O_3	
Density	5.242 g/cm^3
Melting point	1475°C-1565°C
The color	Reddish brown
Purity	99.55%
Size	18 -38 nm
Nano-Al_2O_3	
Density	3.89 g/cm^3
Melting point	2050°C
Color	White powder
Purity	99.9%
Size	3-5 nm

In the current study, conventional Iraqi diesel fuel in fuel stations in Baghdad was used as the base fuel. Table 2 lists this fuel's properties. The biodiesel is produced from waste cooking oil collected from snack shops like frying fish, meat, or some vegetables. Sunflower oil is widely available and widely used in Iraqi restaurants. In order to extract biodiesel, suspended matter and moisture were removed by sedimentation, drying, and filtration. Methanol and KOH were used as catalysts in a stratification process to produce biodiesel. The steps necessary for the stratification process were based on what was stated by the studies of Dhahad et al. [27] and Ezzi et al. [28]. The properties of the prepared biodiesel are shown in Table 2, and the process of preparing biodiesel is shown in Figure 2. Pure pentanol with a purity of 99% (which its properties are detailed in Table 2) was used in this study.

Fuels preparation Due to their hydrocarbon (HC) composition, diesel can be mixed with biodiesel or pentanol easily [29, 30]. The viscosity of diesel will increase when biodiesel is added but will decrease when pentanol is added [31]. The cetane number and calorific value will also decrease as a result of this addition. However, oxygen will increase in the fuel in any case [32]. 80% diesel was combined with 20% biodiesel in this study to make $B_{20}D_{80}$. 10% pentanol was added to 10%Biodiesel and 80 percent diesel. The fuel was called $B_{10}P_{10}D_{80}$. In addition, 0.5 grams/liter of nano alumina and nano iron oxide were mixed with this fuel. $B_{10}P_{10}D_{80}$, the last fuel mix, contained nano-alumina and nano-iron at 0.5 grams/liter each. Based on the studies [33-36], nanoparticles and fuel were mixed for two hours using an ultrasonic vibrator. Figure 3 shows the tested fuels clarifying the differences in their colors due to the mixing process.

Figure 2. The process of separating biodiesel from glycerin after stratification process

Table 2. The fuels used in this study's properties

Material	ρ (kg/l)	Flash Point ℃	Cetane No.	Self-Ignition ℃	LHV (MJ/KG)
Biodiesel	0.850	150	56	271	37.500
Diesel 100	0.819	54	54	254	42.500
Pentanol	0.814	49	20	300	34.650
$B_{20}D_{80}$	0.826	73.2	54.4	257.4	41.300
$B_{10}P_{10}D_{80}$	0.843	63.1	50.8	260.3	41215

Figure 3. The used fuels in the tests

3. EXPERIMENTAL SETUP AND METHODOLOGY

The experiments were conducted using a rig (Figure 4) using an electric dynamo meter with an arm 135 mm and Engine Robin-type single-cylinder engine direct injection air cooled (Table 3). The displacement of this engine is 0.406, the maximum speed is 3000, and the injection angle is 22°BTDC (before the top dead center). The work is done by variable load fixed speed 3000 rpm with a range of loads from minimum to maximum. (0.1-3.5) getting a- the rate of fuel consumption b- the rate of air c- the exhaust gas temperature d- the pollution and Opacity.

Table 3. Characteristics of the test engine

Engine Parameter's	Specification
Engine model	Robin 186F single cylinder
Number of cycle's	Four- stroke
Cooling type	Air -cooled
Bore and stroke	(86×72) mm
Compression ratio	19:1
Fuel injection advance angle	22° BTDC
Rated power and speed	3.5KW at 3000 RPM
Number of nozzles and injection	One - direct
Injector pressure	190 Bar

The equations below were used to assess the engine's performance qualities [37]:

Brake power (kW):

$$BP = \frac{2\pi NT}{60000}$$

Brake means effective pressure (KN/m^2):

$$bmep = bp \times \frac{2 \times 60}{V_{sn} \times N}$$

Fuel mass flow rate (kg/sec):

$$\dot{m_f} = \frac{\dot{v_f} \times 10^{-6}}{1000} \times \frac{\rho_f}{time}$$

Air mass flow rate (kg/sec):

$$\dot{m}_{a,act} = \frac{12\sqrt{h_o \times 0.85}}{3600} \times \rho_{air}\ kg/sec$$

$$\dot{m}_{a_{theo}} = V_{s.n} \times \frac{N}{60 \times 2} \times \rho_{air}\ kg/s$$

BSFC (kg/kW.hr):

$$BSFC = \frac{\dot{m_f}}{b_p} \times 3600$$

Total fuel heat (kW):

$$Q_t = \dot{m_f} \times LCV$$

BTE (%):

$$\eta_{bth} = \frac{bp}{Q_t} \times 100$$

Figure 4. Engine tester rig

4. RESULTS AND DISCUSSIONS

4.1 Brake thermal efficiency

The studied oxygenates have a lower calorific value than diesel. As a result, they have a lower brake thermal efficiency than diesel fuel (Figure 5). Because oxygen is available in oxygenated fuel (B_{20} and $P_{10}B_{10}$), its brake thermal efficiency improves when the engine operates at high loads compared to other load conditions. Composition of the fuel containing oxygen improved combustion significantly. Fuel and spray areas with high concentrations exhibit this effect. A small amount of pentanol in the mixture reduced the viscosity to a reasonable degree, which improved fuel atomization and evaporation within the combustion chamber, resulting in the formation of a better fuel mixture and improved combustion performance [29]. In addition to improving brake thermal efficiency, adding nanoparticles improved the mixtures' thermal braking performance. Nano-alumina produced better results than nano-iron oxide, while both materials produced comparable results when added together. The combustion chamber did not reach temperatures high enough to completely burn the fuel at low loads, resulting in a decrease in braking thermal efficiency compared to diesel. For all mixtures studied, this efficiency increased at medium and high loads, but not comparable to diesel. When nano-alumina was used, this efficiency exceeded that of diesel at high loads. Due to its high viscosity and low cetane number, B_{20} has a 10.77% decrease in brake thermal efficiency. The efficiency of $B_{10}P_{10}$ decreased by approximately 15.12%, because the mixture's calorific value was significantly lower than diesel, and pentanol has the effect of drawing heat from the combustion chamber to evaporation. Among the three mixtures, the Nano-Fe_2O_3 mixture decreased by 9.52%, and the $B_{10}P_{10}+Al_2O_3+Fe_2O_3$ mixture decreased by 5.03%. Compared to diesel, there was a slight increase of 0.4% in the $B_{10}P_{10}+Al_2O_3$ mixture. Thermal brake efficiency was improved with nanoparticles due to their increased luminescence and heat transfer during combustion. It appears, however, that other factors play a role in this process, the most important of which is the type and size of nanoparticles. Alumina nanoparticles have a smaller size than iron oxide nanoparticles. Nano-Al_2O_3 mixtures are more stable and have better distribution and spread than nano-Fe_2O_3. Consequently, both hypotheses were supported by the analytical results.

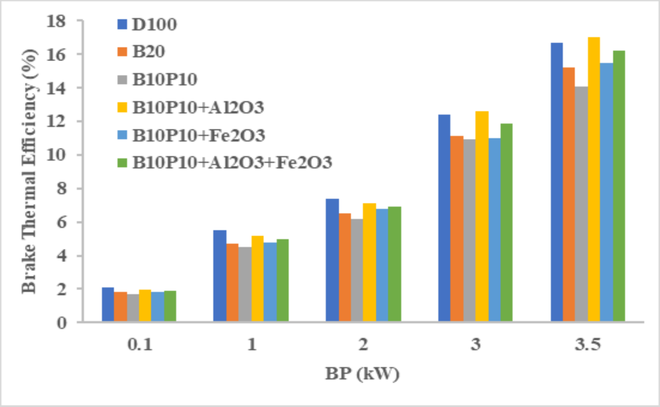

Figure 5. Brake thermal efficiency variations with load for the studied fuels

4.2 Brake specific fuel consumption (BSFC)

Figure 6 illustrates how oxygenates affect the BSFC under different engine load conditions. Due to their lower calorific value, biodiesel and pentanol increased BSFC. A high evaporation temperature (especially alcohol) reduces the heat inside the combustion chamber because part of it is absorbed by fuel evaporation. Thus, combustion deteriorates and fuel consumption increases due to a decrease in cylinder temperature, especially at low loads. High engine loads result in a slight improvement in BSFC. Improvements in thermal cycle efficiency, higher combustion chamber temperatures, and mixture evaporation are responsible for these improvements. A significant decrease in BSFC is observed when using a nano-alumina blend, resulting from the increase in braking power. As compared to diesel fuel, BSFC increases by 26.08% when working with Biodiesel mixtures. The $B_{10}P_{10}D_{80}$ mixture had a fuel consumption increase of approximately 30.4% over diesel. In addition to the lower calorific value, oxygenates have lower braking power and combustion properties, especially at low loads, so more fuel is injected to achieve the same energy production as diesel fuel. To reach the required combustion efficiency, the mass of fuel burned must increase. In both cases, the results of the BSFC are consistent with those of previous publications [12, 28].

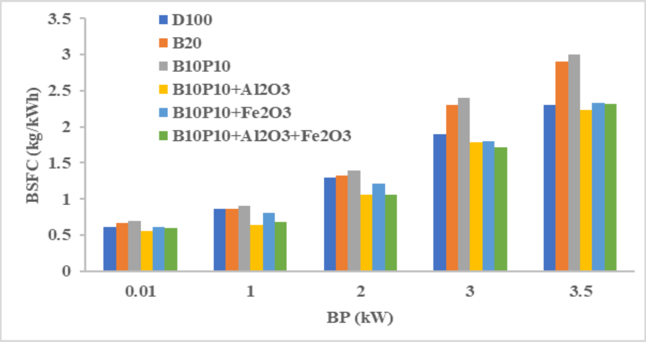

Figure 6. BSFC variations with load for the studied fuels

When compared to diesel, the $B_{10}P_{10}D_{80}+Al_2O_3$ mixture reduced fuel consumption by 3.06%. The results show that both alumina nanoparticles and oxygen content improve combustion efficiency, compensating for a decrease in fuel calorific value. $B_{10}P_{10}D_{80}+Fe_2O_3$ increased brake fuel consumption by 1.3%, which is acceptable although not equivalent to nano-alumina. Compared to diesel, the $B_{10}P_{10}D_{80}+Al_2O_3+Fe_2O_3$ mixture reduces braking fuel consumption by 0.46%. A large part of the decrease in consumption can be attributed to Al_2O_3 nanoparticles. By adding nanoparticles, BSFC decreases because the calorific value of the fuel increases. Fuel is more thermally efficient when nanoparticles are present, as a result of which the ignition delay period is reduced, causing a reduction in fuel consumption, especially when operating at high loads. The results show that $B_{10}P_{10}D_{80}+Al_2O_3$ blends tend to be more efficient and less energy-intensive.

4.3 Exhaust temperature (EGT °C)

EGT (exhaust gas temperature) differs based on the fuel type and applied load (Figure 7). Diesel mixtures with oxygenates have lower EGT than diesel alone. Oxygenate mixtures have a lower specific heat than diesel, which explains this result. These mixtures also take longer to ignite. As a result, the injection timing needs to be changed when working with oxygenates. During this time, the atomized fuel inside the combustion chamber will evaporate, mix, and ignite. $B_{20}D_{80}$ and $B_{10}P_{10}D_{80}$ had lower EGTs than diesel by 4.52% and 9.2%, respectively. Etaiw et al. [31] reports similar results to those of the present study.

Working with nanoparticle-containing mixtures reduces the temperature gap between exhaust gases compared to diesel. As compared to diesel, the $B_{10}P_{10}D_{80}+Al_2O_3$ mixture increased EGT by 0.07%. $B_{10}P_{10}D_{80}+Fe_2O_3$ and $B_{10}P_{10}D_{80}+Al_2O_3+Fe_2O_3$ showed lower results than diesel by approximately 6.01% and 3.5%, respectively. As a result, nanoparticles enhance combustion and enable it to perform like diesel fuel.

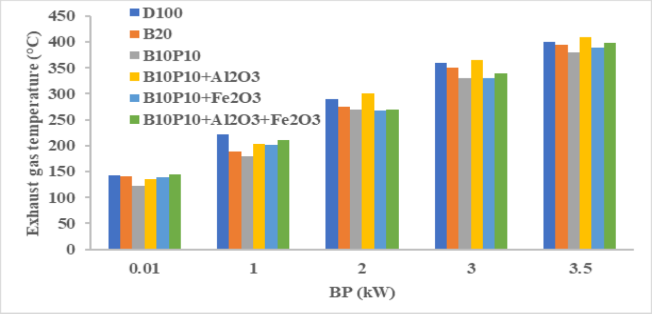

Figure 7. EGT variations with load for the studied fuels

4.4 Unburned hydrocarbons (HC) levels

Figure 8 shows similar impacts on hydrochloric and carbon monoxide emissions. As engine loads increased, HC and CO concentrations increased. The use of mixtures significantly reduces emissions of hydrocarbons (HC) and carbon monoxide (CO). Incomplete oxidation of fuel produces both HC and CO. There is an abundance of oxygen in the fuel used. When using medium and high loads, these pollutants are lower than diesel, while when using low loads, they are higher than diesel. At 8.08% and 9.5% respectively, $B_{20}D_{80}$ and $B_{10}P_{10}D_{80}$ emit less HC than diesel. Using $B_{10}P_{10}D_{80}+Al_2O_3$ mixture reduced the HC concentration by 18.18% compared to diesel. HC concentrations were approximately 13.1% lower when working with $B_{10}P_{10}D_{80}+Fe_2O_3$ and 16.17% lower when working with $B_{10}P_{10}D_{80}+Al_2O_3+Fe_2O_3$ compared to diesel. By improving fuel oxidation and combustion, the combination of nanoparticles and biodiesel-pentanol-diesel mixture was clearly effective in reducing unburned or partially burned hydrocarbon emissions.

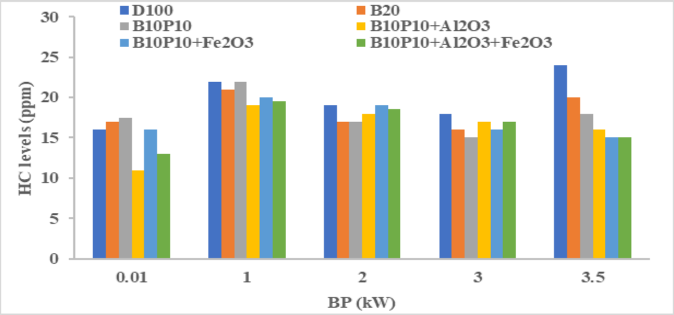

Figure 8. HC level variations with load (Bp) for the studied fuels

4.5 CO levels

When combustion temperatures are low, carbon monoxide (CO) is produced as a sign of incomplete oxidation. The concentration of this pollutant was high at low loads even though oxygenates added to diesel contain a large amount of oxygen (Figure 9). Using these oxygenates causes the cylinder temperature to drop during evaporation due to their high latent heat of vaporization. Carbon monoxide (CO_2) levels rise as a result. Increased levels of carbon monoxide (CO_2) and hydrocarbons (HC)can be caused by prolonged ignition delays of oxygenators. According to these results, the research conducted by Gowrishankar and Krishnasamy [32], Altarazi et al. [33] was consistent. The CO emissions of B20D80 and B10P10D80 are lower than diesel, at 17.46% and 21.9%, respectively. When compared with diesel, the CO concentration was reduced by 33.9% when using $B_{10}P_{10}D_{80}+Al_2O_3$., $B_{10}P_{10}D_{80}+Fe_2O_3$ and $B_{10}P_{10}D_{80}+Al_2O_3+Fe_2O_3$ resulted in lower CO concentrations than diesel by approximately 17.3% and 31.7%, respectively. Carbon monoxide (CO_2) emissions were clearly reduced with nanoparticles and a biodiesel-pentanol-diesel blend by improving fuel oxidation and combustion.

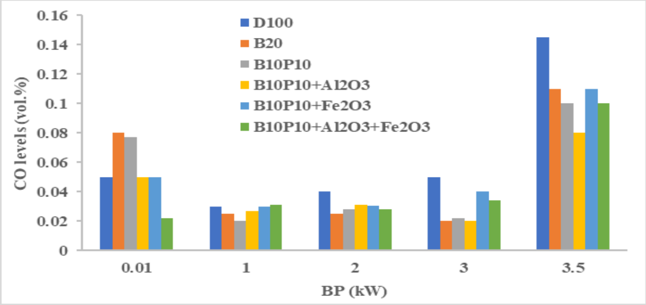

Figure 9. CO level variations with load for the studied fuels

4.6 NOx levels

When working at low engine loads, oxygenated mixtures result in low NOx levels (Figure 10). These concentrations are increased by nano-blends at these loads. According to Dhahad et al. [15] and Alani et al. [34], this decrease is due to lower flame temperatures during combustion. Medium and high loads produce higher NO_x emissions from oxygenated mixtures than diesel. This increase is mainly caused by high combustion temperatures within the combustion chamber. When engine loads increase, NOx levels increase [35]. In oxygenated mixtures, oxygen enhances NO_x formation [36]. As the studies of Han et al. [37] and Zhang et al. [38] explained, adding biodiesel and pentanol to diesel results in a lower cetane value, which results in an increase in the ignition delay period, thus increasing the amount of fuel injected into the combustion chamber. Nitrogen oxide (NO_x) levels increase due to all this.

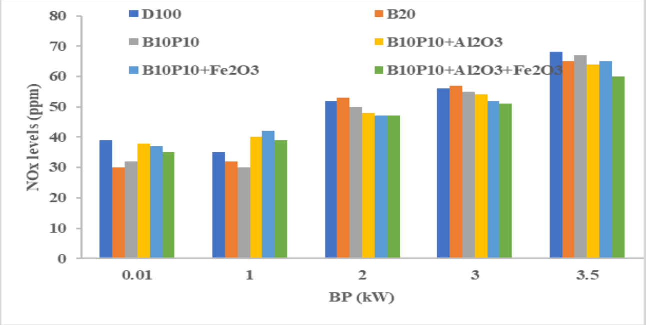

Figure 10. NO_x level variations with load for the studied fuels

4.7 Smoke opacity

At variable engine loads, Figure 11 shows the effect of adding biodiesel and pentanol to diesel on exhaust opacity. The cold combustion chamber produces poor combustion, resulting in high smoke opacity at startup and at low loads [39, 40]. Across all fuel types studied, the opacity decreases at medium and high loads. Because $B_{20}D_{80}$ and $B_{10}P_{10}D_{80}$ contain oxygen, the opacity level is reduced when working with them, which improves combustion efficiency. When working with these two mixtures, the opacity decreased by 14.977% and 15.11 percent, respectively. As the oxygen content of the diesel and oxygenate mixture increases, the opacity decreases, and this is evident at high-loading conditions. Dhahad et al. [41] showed that oxygenates enhanced the oxidation of diesel and improved diffuse combustion during expansion and exhaust phases. Fayad et al. [42] found that oxygen added to diesel lowers smoke opacity, which is consistent with this study's results. When nanoparticles are added to the mixture, the opacity of smoke clearly decreases. It interacts with the sulfate atoms in the fuel and reduces the nuclei required for sulfate molecules to grow, thus improving combustion quality. $B_{10}P_{10}D_{80}$+Al_2O_3, $B_{10}P_{10}D_{80}$+Fe_2O_3, and $B_{10}P_{10}D_{80}$+Al_2O_3+Fe_2O_3 all reduced smoke opacity by 31.49%, 24.66% and 27.53%, respectively, compared to diesel fuel. $B_{10}P_{10}D_{80}$+Al_2O_3 caused the greatest decrease in smoke opacity, despite the fact that the remaining nano-blends also experienced reductions in opacity.

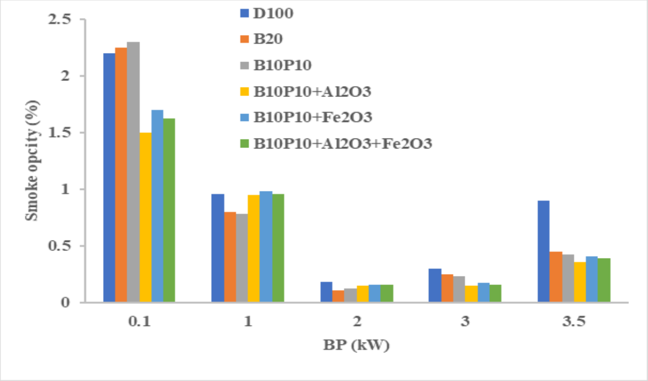

Figure 11. Smoke opacity level variations with load for the studied fuels

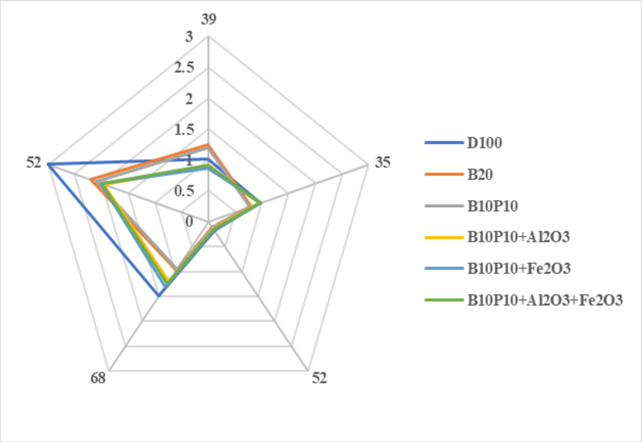

Figure 12. NOx-smoke opacity trade-off variations with load for the studied fuels

4.8 NOx-smoke opacity trade-off

As a trade-off between bias and variance, a trade-off is the act of giving up one advantage for another. In other words, it balances between being too complex (high variance) and too biased (high bias). It results in accurate and generalizable results by balancing these two features. It is evident from Figure 12 that nitrogen oxide reductions cause smoke opacity to increase, and vice versa. In this case, the trade-off is crucial because it reveals whether the fuel used results in higher or lower levels of both pollutants. According to the figure, the tested mixtures reduced smoke opacity but did not reduce NOx significantly. Ezzi et al. [28] and Fayad et al. [43] support these results.

5. CONCLUSIONS

Using oxygenated mixtures and nano-alloys, we evaluated the performance and pollutants of a single-cylinder diesel engine. This study aims to provide fuel with similar performance to diesel while emitting fewer pollutants. The study's major finding is that the BSFC values increased by a maximum of 26.08% when $B_{20}D_{80}$ was used while when oxygenates were added to diesel ($B_{10}P_{10}D_{80}$) the maximum increase was 30.4% when oxygenates were added to $B_{10}P_{10}D_{80}$. Nevertheless, the increase was approximately 1.3% and 0.46% when working with $B_{10}P_{10}D_{80}$+Fe_2O_3 and $B_{10}P_{10}D_{80}$+Al_2O_3+Fe_2O_3 mixtures. A decrease of approximately 3.06% occurred with $B_{10}P_{10}D_{80}$+Al_2O_3. Compared to diesel, NOx levels were generally lower. $B_{20}D_{80}$, $B_{10}P_{10}D_{80}$, $B_{10}P_{10}D_{80}$+Al2O3, $B_{10}P_{10}D_{80}$+Al_2O_3+Fe_2O_3 and $B_{10}P_{10}D_{80}$+Al_2O_3+Fe_2O_3 decreased HC by 8.08%, 9.5%, 18.18%, 13.1%, and 16.17%, respectively. Compared to conventional fuel, CO levels were reduced by 17.46%, 21.9%, 33.9%, 17.3%, and 31.7%. In the oxygenated mixtures, smoke opacity was higher than in diesel, while in nano mixtures, it was lower. Compared to diesel, this opacity decreases at medium and high loads. All other mixtures did not achieve the same levels of engine performance or pollution reduction with $B_{10}P_{10}D_{80}$+Al_2O_3. Nanoparticles with very small sizes are found to have a better effect on the stability and combustion of nanofluid.

REFERENCES

[1] Wilde, L.D., Keserü, I., Macharis, C., Vanhaverbeke, L. (2023). Finding alternatives for the traditional diesel-powered company car: A conjoint analysis approach. Frontiers in Sustainability, 4: 1114437. https://doi.org/10.3389/frsus.2023.1114437

[2] Rony, Z.I., Mofijur, M., Hasan, M.M., Rasul, M.G., Jahirul, M.I., Ahmed, S.F., Kalam, M.A., Badruddin, I.A., Khan, T.M.Y., Show, P.L. (2023). Alternative fuels to reduce greenhouse gas emissions from marine transport and promote UN sustainable development goals. Fuel, 338: 127220. https://doi.org/10.1016/j.fuel.2022.127220

[3] Chaichan, M.T. (2018). Performance and emission characteristics of CIE using hydrogen, biodiesel, and massive EGR. International Journal of Hydrogen Energy, 43(10): 5415-5435. https://doi.org/10.1016/j.ijhydene.2017.09.072

[4] Liu, J.H., Zhang, X.C., Tang, C., Wang, L.J., Sun, P., Wang, P. (2023). Effects of palm oil biodiesel addition on exhaust emissions and particle physicochemical characteristics of a common-rail diesel engine. Fuel Processing Technology, 241: 107606. https://doi.org/10.1016/j.fuproc.2022.107606

[5] Ekaab, N.S., Hamza, N.H., Chaichan, M.T. (2019).

Performance and emitted pollutants assessment of diesel engine fuelled with biokerosene. Case Studies in Thermal Engineering, 13: 100381. https://doi.org/10.1016/j.csite.2018.100381

[6] Saleh, A.M. (2020). Effect of higher alcohol (pentanol-heptanol)–biodiesel–diesel fuel blends on the performance and emission characteristics of a direct-injection diesel engine's. IOP Conference Series: Materials Science and Engineering, IOP Publishing, 928: 022157. https://doi.org/10.1088/1757-899X/928/2/022157

[7] Hua, Y. (2024). Research progress of higher alcohols as alternative fuels for compression ignition engines. Fuel, 357: 129749. https://doi.org/10.1016/j.fuel.2023.129749

[8] Pullagura, G., Vanthala, V.S.P., Vadapalli, S., Bikkavolu, J.R., Barik, D., Sharma, P., Bora, B.J. (2024). Enhancing performance characteristics of biodiesel-alcohol/diesel blends with hydrogen and graphene nanoplatelets in a diesel engine. International Journal of Hydrogen Energy, 50(B): 1020-1034. https://doi.org/10.1016/j.ijhydene.2023.09.313

[9] Chaichan, M.T., Kadhum, A.A.H., Al-Amiery, A.A. (2017). Novel technique for enhancement of diesel fuel: Impact of aqueous alumina nano-fluid on engine's performance and emissions. Case Studies in Thermal Engineering, 10(C): 611-620. https://doi.org/10.1016/j.csite.2017.11.006

[10] Zhang, Z.H., Balasubramanian, R. (2017). Effects of cerium oxide and ferrocene nanoparticles addition as fuel-borne catalysts on diesel engine particulate emissions: Environmental and health implications. Environmental Science & Technology, 51(8): 4248-4258. https://doi.org/10.1021/acs.est.7b00920

[11] Dhahad, H.A., Chaichan, M.T. (2020). The impact of adding nano-Al_2O_3 and nano-ZnO to Iraqi diesel fuel in terms of compression ignition engines' performance and emitted pollutants. Thermal Science and Engineering Progress, 18: 100535. https://doi.org/10.1016/j.tsep.2020.100535

[12] Ekab, N.S., Salam, A.Q., Abd, A.O., Chaichan, M.T. (2023). Effect of Al_2O_3 nanoparticles on the compression ignition performances and emitted pollutants of a diesel engine. Fluid Dynamics & Materials Processing, 19(11): 2847-2861. https://doi.org/10.32604/fdmp.2023.028874

[13] Chaichan, M.T. (2018). Combustion and emission characteristics of E85 and diesel blend in conventional diesel engine operating in PPCI mode. Thermal Science and Engineering Progress, 7: 45-53. https://doi.org/10.1016/j.tsep.2018.04.013

[14] Nguyen, V.N., Nayak, B., Singh, T.J., Nayak, S.K., Cao, D.N., Le, H.C., Nguyen, X.P. (2024). Investigations on the performance, emission and combustion characteristics of a dual-fuel diesel engine fueled with induced bamboo leaf gaseous fuel and injected mixed biodiesel-diesel blends. International Journal of Hydrogen Energy, 54: 397-417. https://doi.org/10.1016/j.ijhydene.2023.06.074

[15] Dhahad, H.A., Chaichan, M.T., Megaritis, T. (2019). Performance, regulated and unregulated exhaust emission of a stationary compression ignition engine fueled by water-ULSD emulsion. Energy, 181: 1036-1050. https://doi.org/10.1016/j.energy.2019.05.200

[16] Altarazi, Y.S.M., Yu, J.L., Talib, A.R.A., Gires, E., Ghafir, M.F.A., Lucas, J., Yusaf, T. (2022). Effects of biofuel on engines performance and emission characteristics: A review. Energy, 238: 121910. https://doi.org/10.1016/j.energy.2021.121910

[17] Veerabadran, V., Veerasigamani, M., Shanmugam, S. (2020). Effect of carbon nanotube material in diesel engine with exhaust gas recirculation. Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, 1-14. https://doi.org/10.1080/15567036.2020.1729901

[18] Tyagi, H., Phelan, P.E., Prasher, R., Peck, R., Lee, T., Pacheco, J.R., Arentzen, P. (2008). Increased hot-plate ignition probability for nanoparticle-laden diesel fuel. Nano Letters, 8(5): 1410-1416. https://doi.org/10.1021/nl080277d

[19] Basha, J.S., Anand, R.B. (2014). Performance, emission and combustion characteristics of a diesel engine using Carbon Nanotubes blended Jatropha Methyl Ester Emulsions. Alexandria Engineering Journal, 53(2): 259-273. https://doi.org/10.1016/j.aej.2014.04.001

[20] Wen, L.B., Wang, Y., Lu, D.L., Hu, S.Y., Han, H. (2010). Preparation of KF/CaO nanocatalyst and its application in biodiesel production from Chinese tallow seed oil. Fuel, 89(9): 2267-2271. https://doi.org/10.1016/j.fuel.2010.01.028

[21] Seffati, K., Honarvar, B., Esmaeili, H., Esfandiari, N. (2019). Enhanced biodiesel production from chicken fat using CaO/$CuFe_2O_4$ nanocatalyst and its combination with diesel to improve fuel properties. Fuel, 235: 1238-1244. https://doi.org/10.1016/j.fuel.2018.08.118

[22] Tomar, M., Kumar, N. (2020). Effect of multi-walled carbon nanotubes and alumina nano-additives in a light duty diesel engine fuelled with schleichera oleosa biodiesel blends. Sustainable Energy Technologies and Assessments, 42: 100833. https://doi.org/10.1016/j.seta.2020.100833

[23] Shekofteh, M., Gundoshmian, T.M., Jahanbakhshi, A., Heidari-Maleni, A. (2020). Performance and emission characteristics of a diesel engine fueled with functionalized multi-wall carbon nanotubes (MWCNTs-OH) and diesel–biodiesel–bioethanol blends. Energy Reports, 6: 1438-1447. https://doi.org/10.1016/j.egyr.2020.05.025

[24] Selvan, V.A.M., Anand, R.B., Udayakumar, M. (2014). Effect of cerium oxide nanoparticles and carbon nanotubes as fuel-borne additives in diesterol blends on the performance, combustion and emission characteristics of a variable compression ratio engine. Fuel, 130: 160-167. https://doi.org/10.1016/j.fuel.2014.04.034

[25] Chen, A.F., Adzmi, M.A., Adam, A., Othman, M.F., Kamaruzzaman, M.K., Mrwan, A.G. (2018). Combustion characteristics, engine performances and emissions of a diesel engine using nanoparticle-diesel fuel blends with aluminium oxide, carbon nanotubes and silicon oxide. Energy Conversion and Management, 171(2): 461-477. https://doi.org/10.1016/j.enconman.2018.06.004

[26] Ooi, J.B., Ismail, H.M., Tan, B.T., Wang, X. (2018). Effects of graphite oxide and single-walled carbon nanotubes as diesel additives on the performance, combustion, and emission characteristics of a light-duty diesel engine. Energy, 161: 70-80. https://doi.org/10.1016/j.energy.2018.07.062

[27] Dhahad, H.A., Fayad, M.A., Chaichan, M.T., Jaber, A.A., Megaritis, T. (2021). Influence of fuel injection timing

strategies on performance, combustion, emissions and particulate matter characteristics fueled with rapeseed methyl ester in modern diesel engine. Fuel, 306: 121589. https://doi.org/10.1016/j.fuel.2021.121589

[28] Ezzi, A.A., Fayad, M.A., Jubori, A.M.A., Jaber, A.A., Alsadawi, L.A., Dhahad, H.A., Chaichan, M.T., Yusaf, T. (2022). Influence of fuel injection pressure and RME on combustion, NOx emissions and soot nanoparticles characteristics in common-rail HSDI diesel engine. International Journal of Thermofluids, 15: 100173. https://doi.org/10.1016/j.ijft.2022.100173

[29] Zhang, Z.Q., Li, J.T., Tian, J., Xie, G.L., Tan, D.L., Qin, B.Y., Huang, Y.X., Cui. S.W. (2021). Effects of different diesel-ethanol dual fuel ratio on performance and emission characteristics of diesel engine. Processes, 9(7): 1135. https://doi.org/10.3390/pr9071135

[30] Dhahad, H.A., Fayad, M.A., Chaichan, M.T., Jaber, A.A., Megaritis, T. (2021). Influence of fuel injection timing strategies on performance, combustion, emissions and particulate matter characteristics fueled with rapeseed methyl ester in modern diesel engine. Fuel, 306: 121589. https://doi.org/10.1016/j.fuel.2021.121589

[31] Etaiw, S.E.D.H., Elkelawy, M., Elziny, I., Taha, M., Veza, I., Bastawissi, H.A.E. (2022). Effect of nanocomposite SCP1 additive to waste cooking oil biodiesel as fuel enhancer on diesel engine performance and emission characteristics. Sustainable Energy Technologies and Assessments, 52(C): 102291. https://doi.org/10.1016/j.seta.2022.102291

[32] Gowrishankar, S., Krishnasamy, A. (2023). Emulsification–A promising approach to improve performance and reduce exhaust emissions of a biodiesel fuelled light-duty diesel engine. Energy, 263(C): 125782. https://doi.org/10.1016/j.energy.2022.125782

[33] Altarazi, Y.S.M., Talib, A.R.A., Yusaf, T., Yu, J.L., Gires, E., Ghafir, M.F.A., Lucas, J. (2022). A review of engine performance and emissions using single and dual biodiesel fuels: Research paths, challenges, motivations and recommendations. Fuel, 326: 125072. https://doi.org/10.1016/j.fuel.2022.125072

[34] Alani, W.K., Zheng, J., Fayad, M.A., Lei, L. (2022). Enhancing the fuel saving and emissions reduction of light-duty vehicle by a new design of air conditioning worked by solar energy. Case Studies in Thermal Engineering, 30: 101798. https://doi.org/10.1016/j.csite.2022.101798

[35] Chen, Z., Wu, Z.K., Liu, J.P., Lee, C. (2014). Combustion and emissions characteristics of high n-butanol/diesel ratio blend in a heavy-duty diesel engine and EGR impact. Energy Conversion and Management, 78: 787-795. https://doi.org/10.1016/j.enconman.2013.11.037

[36] Alptekin, E. (2017). Evaluation of ethanol and isopropanol as additives with diesel fuel in a CRDI diesel engine. Fuel, 205: 161-172. https://doi.org/10.1016/j.fuel.2017.05.076

[37] Han, J.L., Bao, H.S., Somers, L.M.T. (2021). Experimental investigation of reactivity controlled compression ignition with n-butanol/n-heptane in a heavy-duty diesel engine. Applied Energy, 282: 116164. https://doi.org/10.1016/j.apenergy.2020.116164

[38] Zhang, Z.Q., E, J.Q., Deng, Y.W., Pham, M., Zuo, W., Peng, Q.G., Yin, Z.B. (2018). Effects of fatty acid methyl esters proportion on combustion and emission characteristics of a biodiesel fueled marine diesel engine. Energy Conversion and Management, 159: 244-253. https://doi.org/10.1016/j.enconman.2017.12.098

[39] Hamza, N.H., Ekaab, N.S., Chaichan, M.T. (2020). Impact of using Iraqi biofuel–kerosene blends on coarse and fine particulate matter emitted from compression ignition engines. Alexandria Engineering Journal, 59(3): 1717-1724. https://doi.org/10.1016/j.aej.2020.04.031

[40] Chaichan, M.T., Ekab, N.S., Fayad, M.A., Dhahad, H.A. (2022). PM and NOX emissions amelioration from the combustion of diesel/ethanol-methanol blends applying exhaust gas recirculation (EGR). IOP Conference Series: Earth and Environmental Science, IOP Publishing, 961(1): 012044. https://doi.org/10.1088/1755-1315/961/1/012044

[41] Dhahad, H.A., Ali, S.A., Chaichan, M.T. (2020). Combustion analysis and performance characteristics of compression ignition engines with diesel fuel supplemented with nano-TiO_2 and nano-Al_2O_3. Case Studies in Thermal Engineering, 20: 100651. https://doi.org/10.1016/j.csite.2020.100651

[42] Fayad, M.A., Abed, A.M., Omran, S.H., Jaber, A.A., Radhi, A.A., Dhahad, H.A., Chaichan, M.T., Yusaf, T. (2022). Influence of renewable fuels and nanoparticles additives on engine performance and soot nanoparticles characteristics. International Journal of Renewable Energy Development, 11(4): 1068-1077. https://doi.org/10.14710/ijred.2022.45294

[43] Fayad, M.A., Ibrahim, S.I., Omran, S.H., Martos, F.J., Badawy, T., Jubori, A.M.A., Dhahad, H.A., Chaichan, M.T. (2023). Experimental effect of CuO_2 nanoparticles into the RME and EGR rates on NO_X and morphological characteristics of soot nanoparticles. Fuel, 331(1): 125549. https://doi.org/10.1016/j.fuel.2022.125549

NOMENCLATURE

Al_2O_3	Aluminum oxide
BMEP	Brake means effective pressure
BSFC	Brake-specific fuel consumption
CO	Carbon monoxide
CO_2	Carbon dioxide
Fe_2O_3	Iron oxide
HC	Unburnt hydrocarbons
H_2S	Hydrogen sulfide
NOx	Nitric oxides
PM	Particulate matter
ppm	Part per million
SO_2	Sulfur dioxide