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Investigated kerosene-diesel fuel performance in internal combustion engine

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ABSTRACT

This work aims to identify the impact of blending diesel fuel with kerosene on the engine performance and fuel consumption. In addition, this work aims to find the optimum blending ratio that would not notably drawback the engine performance. Blended diesel fuel with kerosene in volume percentages between 7 and 20% was investigated in a four-strokes, single-cylinder, and internal combustion engine to evaluate the engine performance and fuel efficiency at three torques (2, 4, and 6 N m) and constant speed (2000 rpm). The study involved determining several operational parameters, which are the brake-specific fuel consumption (BSFC Kg/kW.h), brake-specific energy consumption (BSEC MJ/kW.h), brake thermal efficiency (BTE), engine effective power (Ne kW), and the noise intensity (measured in dB). The results show that small volume percentages (up to 14%) do not significantly lower the engine performance and fuel consumption. Specifically, the losing in BSFC from blending ratios of 7% and 14% are only 3.8% and 9.6%, respectively. The blending of diesel fuel with kerosene can help minimizing the pollutant emission and decrease the engine noise intensity. Thus, this work concluded that diesel fuel could be blended with kerosene up to 14% without significantly reducing engine performance and fuel efficiency.

1. Introduction

The emission of pollutants such as greenhouse gases and particulate matter (PM) was identified as the mean reason for global warming, which is a sever issue that threatens all countries (Alalwan et al., 2022). Thus, the focus is now on reducing the emissions resulting from the combustion of fossil fuels or finding alternative energy sources such as wind, solar energy, or other green energy sources. However, due to the increasing demand for energy every year and the limitation of the green energy production capacity, it is impossible to shift entirely to green energy sources in the next few decades. Therefore, it is crucial to focus on improving the quality of the current fuels to minimize their emissions.

Diesel fuel is widely used in various kinds of machines, especially in vehicles' engines, which has been identified as an important source of pollution (Albayati et al., 2021) that has adverse effects on the environment and the health of all living (Mohammed et al., 2022). For this reason, it is essential to find an economical method to improve diesel fuel to reduce its emissions. Adding improvement additives to fuels has attracted significant attention because of their favourable influence on the quality of the fuel and its economic aspects. Adding these additives should aim to reduce the emissions with keeping acceptable fuel performance resulting in appropriate engine efficiency, which has been the focus of several researchers such as the work of Nour et al., who used pentanol and octanol and reported promising efficiency (Nour et al., 2019), as well as other works as reported by Ahmed et al. (Ahmad et al., 2022). Kerosene has been suggested for blinding with diesel due to the positive influence on the cold flow of diesel, which is attributed to its

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ability to dilute the unfavorable paraffin waxes that exist in the diesel as reported by Patial et al. (Patil and Thipse, 2014). In addition, Gad et al. investigated using a mixture of waste cooking oil biodiesel with gasoline and kerosene in a diesel engine with testing the combustion and emissions and compared the results with that of fossil diesel. They observed an obvious decreases in the peak cylinder pressures and the emission of Co, HC, and smoke (Gad and Ismail, 2021).

However, experimental investigations of blending diesel with kerosene did not receive enough attention due to some negative aspects, such as lowering the kinematic viscosity, as reported by Baral and Raine (2009). In addition, Yadav et al. (2005) reported that this blending resulted in reducing the percent of opacity value, while Bergstrand (2007) spotted the light on the kerosene cetane number, which is lower than that of diesel and increased the ignition delay, which is considering a negative impact, even with other positive aspects that he reported such as lowering soot emissions at low loads. Other researchers investigated kerosene influence on spark ignition (SI) engines used for electric generation and reported better cost-effective than gasoline and less noise than diesel (Pathak et al., 2005).

Several researchers have reported a significant reduction in emissions from blending diesel with kerosene such as Elsharkawy et al. who noticed a significant reduction in NOx emission compared to pure diesel, (Elsharkawy et al., 2021), and Ekaab et al. who reported lower emission of PM, HC, CO in kerosene diesel mixture compared to pure diesel (Ekaab et al., 2019). On the other hand, some other reported the ability of blending diesel fuel with kerosene without any notable negative impact on the engine efficient, but with increasing the rate of pollutant emissions (Mustak and Ahmed, 2018). This contradictory results emphasize investigating this topic, taken in account that only a few investigations have been done to evaluate the impact of kerosene on engine performance. Thus, this work has been undertaken to identify the performance of an internal-combustion diesel engine using various kerosene-diesel volume percentages as fuel. This study investigated the influence of blending kerosene with diesel in the ratio of 7, 14, and 20% of kerosene on a four-strokes, single-cylinder, and pneumatic-cooling diesel engine. The evaluation of using the blended fuel was done by identifying the main engine efficiency parameters, which are BSFC (Kg/KW.h), Ne (kW), BSEC (MJ/KW.h), BTE (η_{bth}), and the noise intensity (measured in dB). The aim of this study is to identify the optimum blending ratio that would not notably drawback engine efficient.

2. Materials, instruments, and experimental procedure

2.1. Test setup

The current work was done using a laboratory internal-combustion, four-strokes, single-cylinder, and pneumatic-cooling diesel engine type TD 212 (Fig. 1-a). The engine maximum power and torque are 3.5 kW and 16 Nm at 3600 rev.min^{-1}, respectively, engine capacity 232 cm^3, cylinder bore 69 mm, fuel injection time 24^{o} BTDC, and the compression ratio 22:1. The engine was associated with a hydraulic dynamometer through a coupling to load various torques on the machine, while the machine performance was recorded by a measurement unit (Fig. 1-b). In this unit, all experimental readings from the compression ignition (CI) engine have recorded. The measurement's unit has a glass tube, which is used in measuring the consumption rate of fuel. In addition, it has a gauge to monitor the engine load and number of revolutions as well as a power meter. A calibrated burette and a stopwatch were used to calculate the mass flowrate of pumped fuel. To scale the noise level, a sound level meter (Onsoku) was used. More details about the specifications of the engine, dynamometer, and measuring unit, as well as the experimental procedure, are presented elsewhere (Hassan et al., 2021).

The work was done using four types of fuel, which are non-blending (pure) diesel and three blending with kerosene in volume percentages of 7, 14, and 20. These types will be mentioned later in the text as PD, KD7, KD14, and KD20, respectively. Chosen of these blending ratios was done based on the recommendations to fill the gap in the literatures about these ratios (Lin Tay et al., 2020). Diesel and kerosene fuels were obtained from Kut Oil Depot- Iraq, while the three other types of blending fuel were prepared in our laboratory. The experimental procedure is described in a previous work, where three torques (2, 4, and 6 N m) were used with a fixed speed of 2000 rpm. Chosen these parameters was done to show the influence of increasing torque value on the engine performance using blending fuels comparing with non-blending fuel. Each experiment was triplicated, and the average value was presented.

2.2. Tested parameters

Engine performance was evaluated by various parameters, which are BSFC (kg/kW.h), Ne (kW), BSEC (MJ/kW.h), BTE (η_{bth}), and the noise intensity (measured in dB). These parameters are calculated according to equations (1)–(5), respectively (Mohanty, 2007),

$$\mathrm{BSFC} = \frac{m^{o}f}{B.P} \tag{1}$$

$$N_e = \frac{MF}{\mathrm{BSFC}} \tag{2}$$

$$\mathrm{BSEC} = \mathrm{BSFC} \times \mathrm{LHV} \tag{3}$$

$$B.P = \frac{2 \times \pi NT}{60000} \tag{4}$$

$$\eta_{bth} = \frac{B.P}{m^{o}f \times CV} \tag{5}$$

where $m^{o}f$ is the fuel consumption rate (g/s) , $B.P$ is the power produced (W), MF is the fuel mass flow rate (Bayraktar, 2008), LHV is the lower heating value (MJ/kg) (Datta et al., 2014), T is the brake load of the

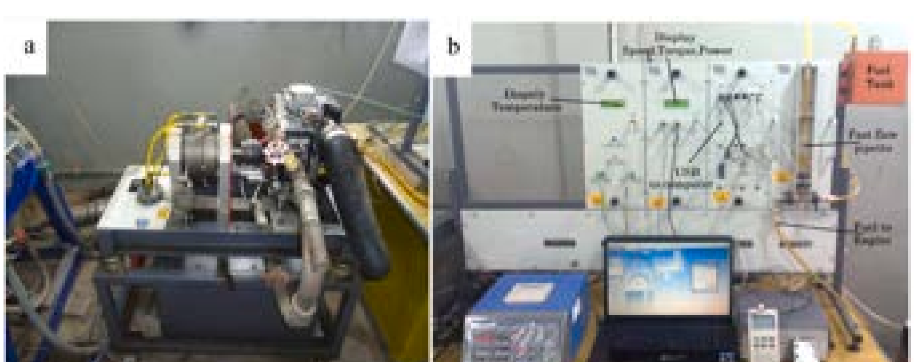

Fig. 1. (a) TD212 engine and (b) measurement unit.

tested engine (N.m), N is the speed (rpm) (Maniyath et al., 2015), and CV is the heat value of the fuel kJ/kg (Kishor et al., 2013). The noise level of the engine was measured in decibels (dB) using a sound level meter. Table 1 shows the physical properties of the four fuel types, which were done by Kut Oil Depot laboratory- Iraq.

3. Results and discussion

This work tested blending diesel with kerosene up to 20%. Above this volume ratio, there would be a significant decrease in the viscosity and density of the mixed fuel, which leads to a reduction in the fuel lubricity and results in potential wear issues in fuel injector designs and sensitive fuel injection pumps (Patil and Thipse, 2014). Fig. 2 shows the influence of blending diesel with kerosene on BSFC value, which is a direct indicator of fuel efficiency by showing the fuel consumption rate per produced power. The results show that BSFC values of KD7 at different loads are very close to that of diesel fuel, while increasing the blending ratio shows a more significant increase in the BSFC values, which indicating decreasing the overall efficiency of blended fuels. Specifically, at torque of 2.0 N m, PD, KD7, KD14, and KD20 showed BSFC values of 0.52, 0.54, 0.57, and 0.59 (Kg/KW.hr), respectively. Kerosene has lower heating value than diesel, and therefore kerosene-diesel mixture will have lower heating value than pure diesel, which resulted in higher BSFC value (Ekaab et al., 2019). These results indicate that the losses in the BSFC values are 3.8, 9.6, and 13.4%, respectively. At the highest load (6.0 N m), there was decreasing in the BSFC values of all types of fuel. Specifically, BSFC values of PD, KD7, KD14, and KD20 were 0.258, 0.265, 0.275, and 0.278 (Kg/KW.hr), respectively. This lowering in BSFC values was expected due to elevating the applied torque. When increasing the engine speed, fuel will have a more chance to complete ignition, which improves fuel efficiency indicating by BSFC value. However, the increase in BSFC values with increasing the blending ratio at 6.0 N m were 2.7, 6.5, and 7.7% for KD7, KD14, and KD20, respectively. This means that the increase in fuel consumption is lower at higher loads. However, due to the lower cetane number of kerosene, there were higher ignition delays, which were observed obviously at the highest blending ratio (Bayraktar, 2008). The lower heat value and latent heat of vaporization of kerosene resulted in reduced heat generated inside the combustion chamber, which leads to decreased engine noise but increases the physical delay period in the first step of combustion. The short raising of ignition delay is helpful for better burning process, which can lower emissions. On the other hand, the high ignition delay, which is resulted from the high blending ratio, can cause a higher cylinder pressure (Shahabuddin et al., 2013; Zheng et al., 2015).

Fig. 3 shows that the adequate power (Ne) of KD7 is very close to that of non-blending diesel, while the decrease in the Ne values is more evident at the higher blending ratios. Specifically, Ne values of PD, KD7, KD14, and KD20 at 2 N m were 3.8, 3.7, 3.5, and 3.4 (KW), respectively. This decrease in the engine efficiency is assigned to the lower cetane number of kerosene compare to diesel (Patil and Thipse, 2015). Reducing the cetane number below the standard value resulted in decrease the charge temperature, which led to longer ignition delays as a result of the difficulties in the ignition and resulted in poor combustion as a result of decrease combustion period (Gnanamoorthi and Devaradjane, 2015). However, the reduction in Ne values when adding 20% of kerosene is only between 7 and 10% for different loads. This is due to the

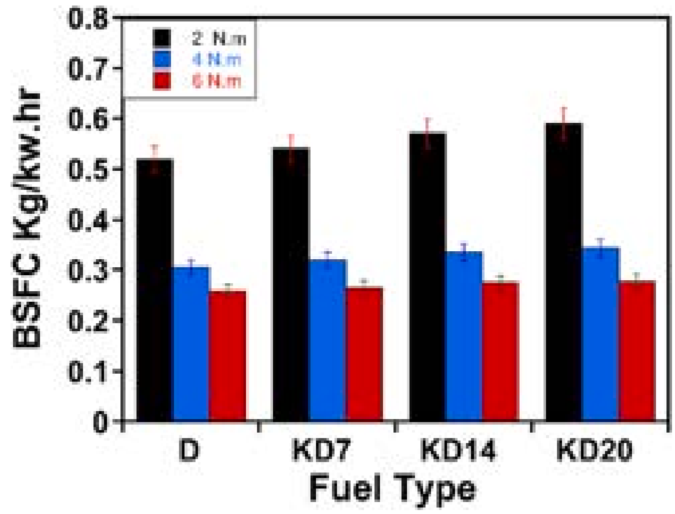

Fig. 2. The effect of mixing diesel fuel with kerosene at 2000 rpm and various blending ratios and different loads on BSFC (kg/kw.hr).

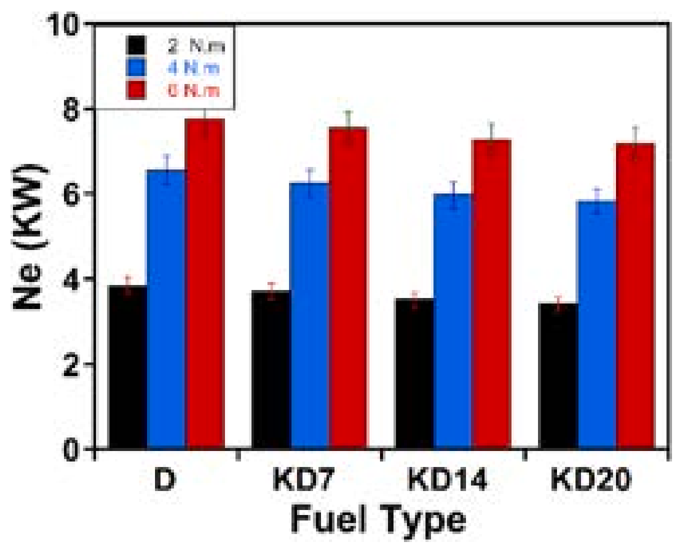

Fig. 3. The effect of mixing diesel fuel with kerosene at 2000 rpm and various blending ratios and different loads on effective power (KW).

close values of cetane number for both fuels and also due to the shorter branches of kerosene comparing to diesel fuel, which improves the fuel efficiency in the engine (Fayyazbakhsh and Pirouzfar, 2017).

The influence of mixing diesel with kerosene on BSEC value is presented in Fig. 4, which shows decreasing BSEC values with increasing loads for all fuel types. Generally, raising the blending percentage increases BSEC values for all fuel types. However, low blending ratios show very close BSEC values compared with that of PD. Specifically, BSEC values of PD, KD7, KD14, and KD20 at 2 N m were 27.7, 28.8, 30.4, and 31.5 MJ/kW.hr, respectively. This means that the raise in the BSEC is 3.9, 9.7, and 13.7%, respectively. Similar behaviour was observed for

Table 1
Physical properties of all fuel types.

Fuel type	Density (kg/m^3)	Kinematic Viscosity (cSt) at 40 °C	Cetane #	LCV (MJ/kg)	Surface Tension (N/m at 20 °C)	Latent heat of Vaporization (kJ/kg)
Pure diesel	840.00	2.45	56.0	46.0	0.029	348.9
Pure kerosene	800.0	1.15	42.0	45.00	0.027	251.00
KD7	837.20	2.359	55.02	45.93	0.028	342.10
KD14	834.40	2.268	54.04	45.86	0.028	335.20
KD20	832.00	2.19	53.20	45.80	0.028	329.32

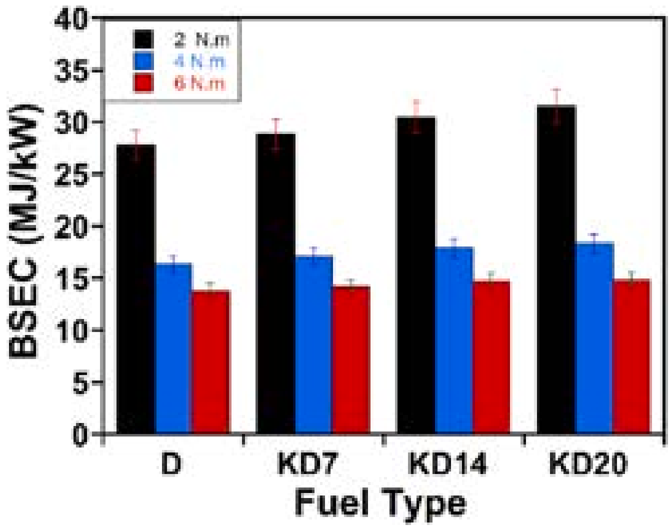

Fig. 4. The effect of mixing diesel fuel with kerosene at 2000 rpm and various blending ratios and different loads on brake specific energy consumption (BSEC MJ/KW.h).

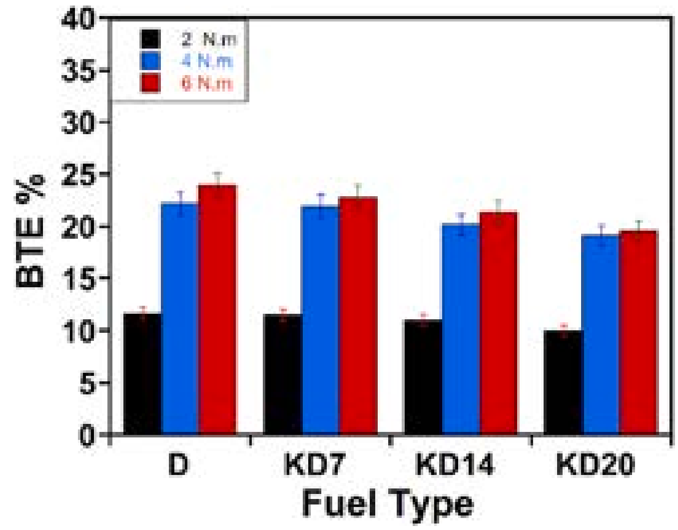

Fig. 5. The effect of mixing diesel fuel with kerosene at 2000 rpm and various blending ratios and different loads on brake thermal efficiency.

elevated torques, where the BSEC values at load 4 N m increased from 16.3 MJ/kw.hr for PD to 17.1, 17.9, and 18.3 MJ/kW.hr for KD7, KD14, and KD20, respectively, while at load 6 N m they increased from 13.8 MJ/kW.hr for PD to 14.1, 14.7, and 14.9 MJ/kW.hr for KD7, KD14, and KD20, respectively. This raise in the BSEC is logically due to increased BSFC values, which resulted in this increase according to equation (2). As mentioned earlier, kerosene has lower heating value than diesel, which means that kerosene-diesel mixture will have lower heating value than pure diesel. This resulting in more consumption of fuel to achieve the same engine efficiency (Kumar et al., 2006).

The losing of 9.7% in BSEC value when using 14% of kerosene is acceptable from the economical perspective at least in oil countries such as Iraq, where the kerosene price is much less than diesel fuel. Specifically, in Iraq the price of a litter of diesel and kerosene fuels are 450 and 150 Iraqi Dinar (the local currency). This means that using 14% of kerosene will save around 10% of the fuel cost per litter, which is equal to the losing percentage in the fuel consumption. However, the aim of using kerosene is to minimize the pollutant emission, which their caption can cost more. In addition, kerosene fuel is produced usually after purification from sulphur compounds, which makes the blended fuel more clean than pure diesel (Ekaab et al., 2019).

The effect of mixing diesel with kerosene on BTE at different loads is presented in Fig. 5, which shows increased BTE values with raising the supplied torque. On the other hand, raising the kerosene percentage lowers the BTE values. In specific, the BTE of PD, KD7, KD14, and KD20 at 2 N m were 11.63, 11.50, 11.0, and 9.99 respectively, while at the load of 4 N m, the BTE values were 22.19, 21.94, 20.18, and 19.09, respectively. Finally, at the load of 6 N m, BET values decrease from 23.90 for PD to 22.79, 21.33, and 19.52 for KD7, KD14, and KD20, respectively. The dropping of BTE values for KD7 at the three loads is between 1.1 and 4.6%, which is an acceptable range taking into account the advantages of reducing the emitted pollutants. The reduction in BTE values for KD14 ranges of 9–14%, while the decrease for KD20 at different loads is between 14 and 18%. Although these percentages are somehow expected, they still higher than that reported by Ekaab et al. who reported a losing of 5.19% when using 20% of biokerosene (Ekaab et al., 2019). BTE is a primer indicator of the ability of the engine to adapt the mixing fuel and provides an analogous understanding of the efficiency of the combustion system to transfer the fuel energy in a mechanical form. Based on that, it can conclud that mixing kerosene with diesel in small percentages to reduce emissions has limited influence on the operation parameters such as BSFC, BSEC, Ne, and BTE.

As expected, increasing the load increases noise intensity, but the noise intensity was less at all tested loads by increasing the blending ratio, as shown in Fig. 6. Specifically, the noise intensity at load value of 2 N m was 83.97, 81.76, 79.65, and 70.75 dB for PD, KD7, KD14, and KD20, respectively. At loads of 4 N m, the intensity values for PD, KD7, KD14, and KD20 were 84.50, 82.82, 80.77, and 71.64 dB, respectively, while intensity values at load of 6 N m were 85.79, 84.11, 82.43, and 80.05 dB respectively. This reduction in noise level is attributed to the mixing of diesel with kerosene, which has a positive influence on the sound intensity in the injection pump and injector. In specific, mixing kerosene with diesel leads to a cooling influence on the cylinder charge because of the differences in the heating value, LHV, stoichiometric fuel to air ratio required for different blended ratios. These parameters would reduce the peak cylinder temperature, which minimizes the machine knocking (Shi et al., 2019).

4. Conclusions

The results show no considerable change in BSFC, Ne, BSEC, and BTE for mixing diesel with kerosene in small percentages at different loads.

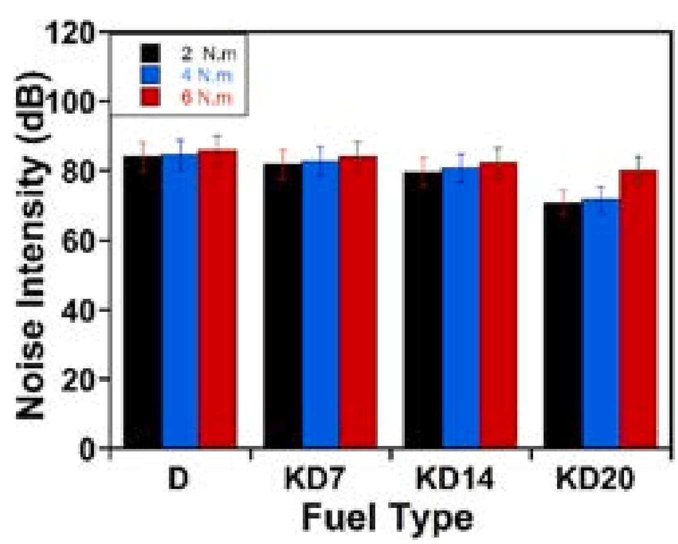

Fig. 6. The effect of mixing diesel fuel with kerosene at 2000 rpm and various blending ratios and different loads on the engine's noise intensity (dB).

Specifically, the loosing in BSFC, BTE, and BSEC for 14% kerosene mixture is less than 10% only, while the loosing in Ne is between 9 and 14%. Raising the mixing percentage above 14% is not recommended because of the apparent reduction in engine efficiency and increasing fuel consumption. However, raising the mixing percentage decreases noise level at all loads. The comparable performance of blended fuel to the non-blending diesel is attributed to their comparable values of cetane number, heat value, and LHV. The lower heat value and latent heat of vaporization of kerosene resulted in reduced heat generated inside the combustion chamber, which leads to decreased engine noise. Thus, this investigation recommends blending kerosene with diesel fuel in a volume percentage of 7 or 14 as a maximum to get the environmental advantages without significantly lowering the engine performance or fuel efficiency.

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Code availability

Software application or custom code.

CRediT author statement

Lizan Mahmood Khorsheed Zangana: Data collecting.

Abdulelah Hameed Yaseen: Methodology, data collection, and Visualization.

Qais Hussein Hassan: Data collecting and Conceptualization.

Malik M. Mohammed: Software, Investigation, and Validation.

Mohammed Fakhri Mohammed: Data Curation.

Hayder A. Alalwan: Project administration, Writing - Original Draft.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Nomenclature

Definition Symbol
brake-specific fuel consumption BSFC
brake-specific energy consumption BSEC
brake thermal efficiency BTE
brake load of the tested engine T
Compression ignition CI
Decibels dB
engine effective power Ne
fuel consumption rate $m^{o}f$
fuel mass flow rate MF
heat value of the fuel CV
hydrocarbons HC
Kerosene7%-diesel 93% KD7
Kerosene14%-diesel 86% KD14
Kerosene20%-diesel 80% KD20
lower heating value LHV
particulate matter PM
power produced B.P.
Pure diesel PD
spark ignition SI
speed (rpm) N

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