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Research Article

The Influence of Water and DEE as Additives with Diesel Fuel in a Light Duty Diesel Engine Generator-An Experimental Investigation

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Abstract: Currently, our global environment has been affected due to the air pollution caused by many sectors (such as automotive, industrial, transportation) in higher magnitudes. Many environmentalists, scientists, researchers, and engineers have contributed their efforts to eradicate the air pollution. It is well known that most of the harmful pollutants are evolved from diesel engine power engines/plants. Considering the objective of enhancing performance and reducing harmful emissions from diesel engine, the current research work has been conducted on mixing Di-Ethyl Ether (DEE) and normal water with normal diesel fuel in definite quantities. The study was carried out in five stages to blend water and DEE with standard diesel fuel. In the first stage, to obtain the baseline readings, normal diesel fuel was experimented in a light-duty, constant-speed diesel engine. Normal water (2% & 4% by volume) was combined with the normal diesel fuel with the aid of emulsifiers (Span 80 & Tween 80) and mechanical stirrer (speed of 3,000 rpm) to obtain the water-blended diesel emulsion fuels in the second stage. In the third stage, DEE was mixed with water-emulsion fuels prepared in the second stage. The stability and properties of the fuels were determined in the fourth stage. In the fifth stage, the prepared stable DEE-water-diesel emulsion fuels were tested in a light-duty, constant-speed diesel engine generator and eventually compared with those of normal diesel fuel. Experimental outcome from all the tested fuels revealed that water and DEE mixed emulsion fuels reflected better performance and reduced harmful emission attributes.

***Keywords*:** surfactants, water + DEE, emissions, light-duty diesel engine

Nomenclature

CI	Compression Ignition
CO_2	Carbon Dioxides
CO	Carbon Monoxides
D	Diesel
HC	Hydrocarbons
NO_x	Nitrogen Oxides
DEE	Di-Ethyl Ether
98D2WSDEE	98% of Diesel + 2% of Water + Surfactant

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96D4WSDEE	96% of Diesel + 4% of Water + Surfactant

1. Introduction

Numerous efforts have been devised by automobile researchers to safeguard the environment against many pollutants (such as Oxides of Nitrogen and Carbon, Hydrocarbons etc.) emitted by diesel engines. To exterminate those harmful pollutants (which are precursor for the global defects like ozone layer depletion, global warming, and acid rain [1]-[3]), numerous researchers have concocted many methods to minimise it in accordance with the stringent emission legislation (Euro VI norms). The automobile researchers, scientists and environmental engineers have contributed their efforts to enhance the mileage and to reduce emissions of diesel engines in a systematic way. Among many methods, most of the automotive professionals [1]-[17] in the technical community preferred fuel modification technique to attain better mileage and reduced emissions trend from the diesel engine. This is due to the fact that fuel modification method involves feasible way to blend any additive (such as organic additive, inorganic additive, nanoparticle additive, water etc.) with base fuel (such as diesel and biodiesel). In the latest fuel modification technology, efforts are underway to incorporate multi-fuel additives with the diesel fuel to investigate the working features of diesel engine in terms of performance and emission characteristics. Hence, in the current investigation, an oxygenated additive cum cetane improver (DEE) and water are selected as potential additives with the diesel fuel, and eventually mixed with specific proportions using a mechanical homogenizer systematically. Henceforth, in this research assessment, the experimental methodology with a focus on uncertainty analysis, and the results and discussions on using theDEE blended water-diesel emulsion fuel in a light-duty diesel engine generator is investigated.

2. Experimental methodology and uncertainty analysis

The current research attempt has been carried out systematically in due respect with the international standards of testing and evaluation of a diesel engine operation. To carry out, the proposed investigation, a light-duty diesel engine generator coupled with an electrical loading was utilized to appraise the performance entities (such as brake thermal efficiency and brake specific fuel consumption) and emission entities (level of NO_x, CO, CO_2, HC) from zero load to full load. The fuel consumption rate of each tested fuel during the experiment was quantified using a glass burette and stopwatch combination, and eventually the brake thermal efficiency values were measured and compared for all the tested fuels. Further, the emissions from the diesel engine generator were measured on using an calibrated KANE gas analyzer. As per the SAE international standard of testing and evaluation of diesel engine, starting and stopping operation of the light duty constant speed diesel engine generator was carried out on using the normal diesel fuel. In this research attempt, totally five stages of investigation have been materialized. In the first stage, performance attribute (both brake thermal efficiency & brake specific fuel consumption) and harmful emission readings (HC, NO_x, CO, CO_2) of normal diesel fuel in a light duty constant speed diesel engine generator was noted and eventually recorded. Normal water (2% & 4% by volume) was combined with the normal diesel fuel with the aid of emulsifiers (Span 80 & Tween 80) and mechanical stirrer (speed of 3,000 rpm) to obtain the water blended diesel emulsion fuels in the second stage. In the third stage, DEE was mixed with water-emulsion fuels which were prepared in the second stage. In the fourth stage, stability and properties of fuels (such as calorific value, density, kinematic viscosity, flash point and fire point) were determined as per the ASTM standards (refer Figure 1 & Table 1).

In the final stage, experimental evaluation in a light duty constant speed diesel engine generator were carried out on using the stable water-diesel emulsions and DEE blended water-diesel emulsions and eventually compared to those readings of normal diesel fuel.

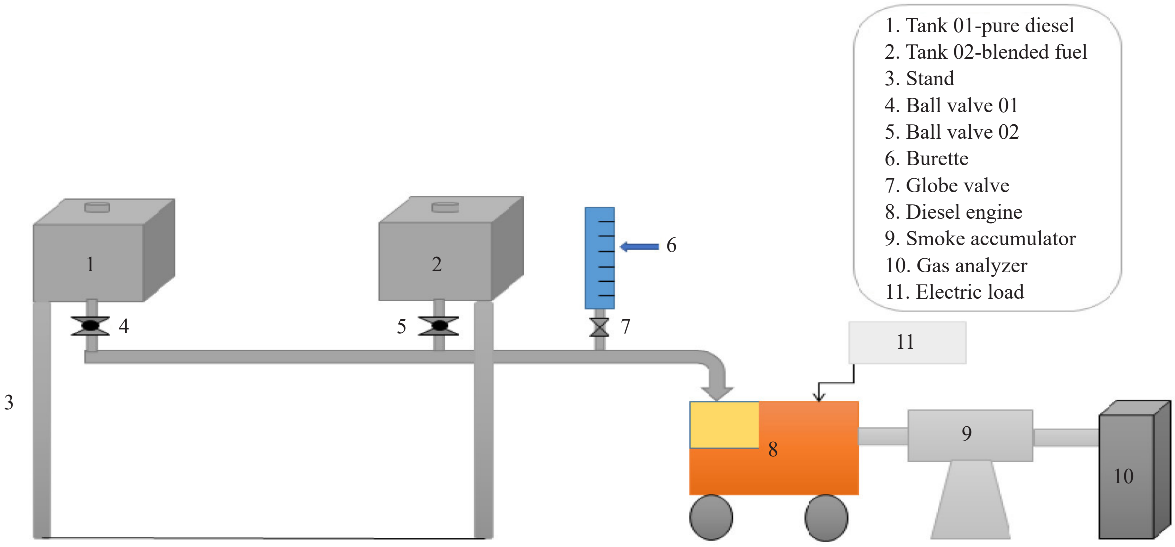

Figure 1. Experimental setup [18]

Table 1. Properties of fuel

Fuel No.	Fuel code	Density (g/cm^3)	Kinematic Viscosity @ 40 ºC (cSt)	Flash point (ºC)	Cetane No.
1	Diesel	0.830	2.10	50	55
2	98D2WSDEE	0.844	3.85	85	70
3	96D4WSDEE	0.849	3.90	88	72

Table 2. Specifications of diesel engine generator

Particulars		Values
Rated output (Watt)	-	5,000
Type	-	Vertical Single Cylinder
Forced Air cooled, 4 Stroke	-	418
Displacement	-	418
Fuel Tank Capacity (L)	-	12.5
Starting System	-	Recoil & Key
Noise Level (@7 M dB)	-	78
Net Weight (kg)	-	120
Voltage (V)	-	230 V
Current	-	25 A
Phase	-	Single-phase
Frequency (Hz)	-	50 Hz
Engine speed	-	3,000 rpm
Lubrication oil	-	SAE40

The diesel engine generator specifications is shown in the Table 2.

The following typical curves were assessed for both diesel and additive blended diesel fuels:

1. Performance features (both Brake thermal efficiency & Brake specific fuel consumption) vs Engine Load.
2. Level of harmful emissions (NO_x, CO, CO_2, HC) vs Engine Load.

3. Uncertainty analysis

In the current experimental research work, there are some possibilities of errors raised from various sources (viz., instruments, environmental conditions, calibration, human observation, visibility conditions etc.). In order to calculate the possible error percentage during the experimentation, uncertainty or experimental error analysis are calculated. In the current investigation, instruments such as KANE gas analyzer, overhead digital stirrer, burette and stopwatch were used. Hence, the uncertainty error percentage for the whole experimentation is calculated as per the Moffat [19] relationship as below:

Uncertainty Error (%)

$$= \sqrt{(NO_x)^2 + (CO)^2 (CO_2)^2 + (HC)^2 + (\text{Burette Reading})^2 + (\text{Digital Ovehesd Stirrer})^2 + (\text{Stop Watch})^2}$$

$$= \sqrt{(1)^2 + (1)^2 + (0.01)^2 + (0.1)^2 + (1)^2 + (1)^2 + (1)^2}$$

$$= 2.238\%$$

4. Results and discussions

The diesel engine generator working features (in terms of performance and emissions level) on using normal diesel fuel and DEE blended water-diesel emulsions are discussed in the succeeding sections.

4.1 *Performance features of the diesel engine generator*

Figures 2 & 3 illustrates the performance features (such as brake thermal efficiency and specific fuel consumption) of the light duty constant speed diesel engine generator for all the tested fuels.

It is eminent from the figures that the Di-Ethyl Ether blended emulsion fuels reflected minimal fuel consumption compared to that of pure diesel fuel starting from the zero load to full load capacity of the diesel engine generator. The presence of cetane improver (i.e., DEE) in the emulsion fuel could have played a vital role on brake specific fuel consumption attribute. It is well known fact that DEE has higher cetane no. (around 125) and could have influenced better combustion (due to micro-explosion effects. Owing to this fact, DEE blended emulsion fuels could have influenced lesser fuel consumption to maintain the speed of the diesel engine generator constant, and simultaneously reflected increased in the brake thermal efficiency. This is possibly due to the fact that both performance features (brake specific fuel consumption & brake thermal efficiency) are inversely related to each other. At the full load (4,000 W), the fuel consumption for the normal diesel fuel was 0.331 kg/kWh; whereas it was 0.298 kg/kWh and 0.274 kg/kWh for the 98D2WSDEE and 96D4WSDEE fuels. A similar trend of enhanced brake thermal efficiency was noted for the DEE water mixed diesel fuels compared to that of normal diesel fuel. At the full load (4,000 W), the brake thermal efficiency for the normal diesel fuel was 25.52%; whereas it was 29.38% and 30.82% for the 98D2WSDEE and 96D4WSDEE fuels respectively.

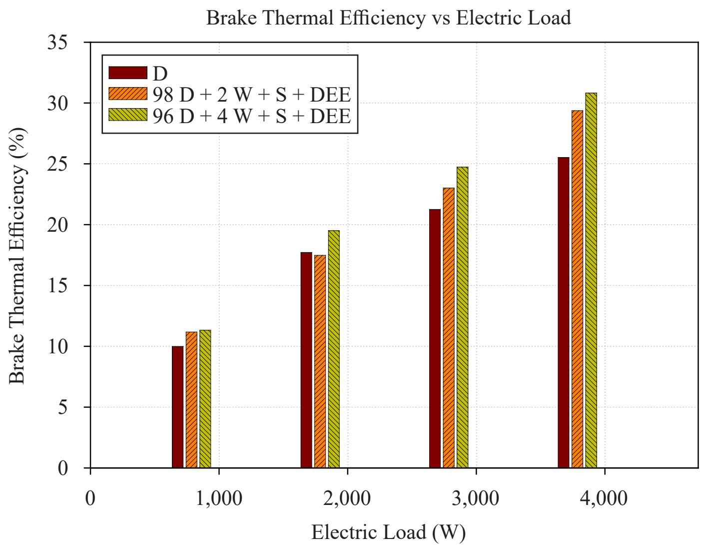

Figure 2. Brake thermal efficiency variation of diesel and water blended diesel fuels

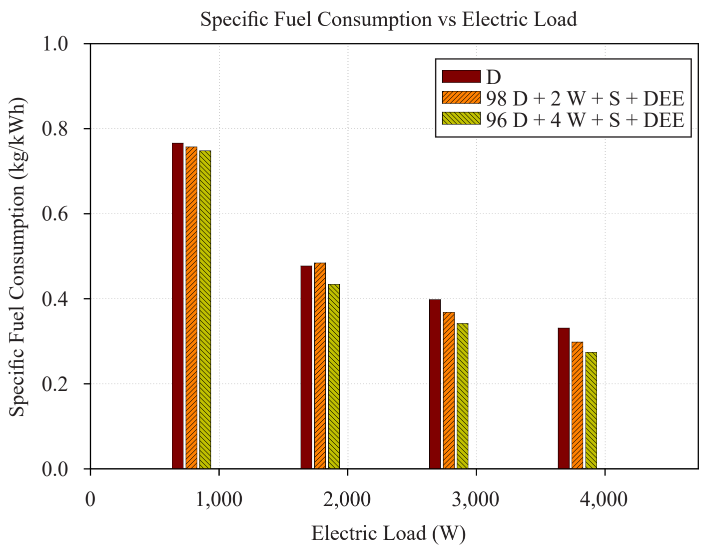

Figure 3. Brake specific fuel consumption variation of diesel and water blended diesel fuels

4.2 *Emission features of the diesel engine generator*

The succeeding Figures 4, 5, 6 & 7 designates the emission points of diesel fuel and DEE + water mixed diesel fuels. Owing to addition of DEE with the diesel fuel, the fuel quality (such as cetane no., flash point etc.) of DEE mixed fuels were improved compared to that of diesel fuel. This could have led to better combustion attributes in the engine cylinder of the diesel engine generator. Due to these reasons, the amount of the emission levels (CO, CO_2, HC, and NO_x) were considerably reduced for the DEE water-diesel emulsions on comparison with that of normal diesel fuel.

The existence of H_2O in diesel fuel has expressively prejudiced to reduce the harmful emissions for the DEE water mixed diesel fuels due to secondary atomization effects explained by Sadhik and Montaha [20] and Abu Zaid [20]. At the full load (4,000 W), the CO emissions for the normal diesel fuel was 0.22% (by vol.); whereas it was 0.09% and 0.05% (by vol.) for the 98D2WSDEE and 96D4WSDEE fuels. A similar trend of reduced NO_x emissions was noted for the water mixed diesel fuels compared to that of normal diesel fuel. At the full load (4,000 W), the level of NO_x emissions for the normal diesel was 412 ppm; whereas it was 380 ppm and 351 ppm for the 98D2WSDEE and 96D4WSDEE fuels respectively. A similar trend of marginal reduction of HC emissions were noted for the water mixed diesel fuels compared to that of normal diesel fuel [21]-[23]. At the full load (4,000 W), the level of HC emissions for the neat diesel was 75 ppm; whereas it was 70 ppm and 61 ppm for the 98D2WSDEE and 96D4WSDEE fuels respectively. Further, it has been noticed that overall cost on preparing the emulsion fuels [24] is less while compared to that of preparing biodiesel blended emulsion fuels. This is due to the fact that the water is cheap and easily available, and the amount of DEE used in the investigation is very lesser in magnitude.

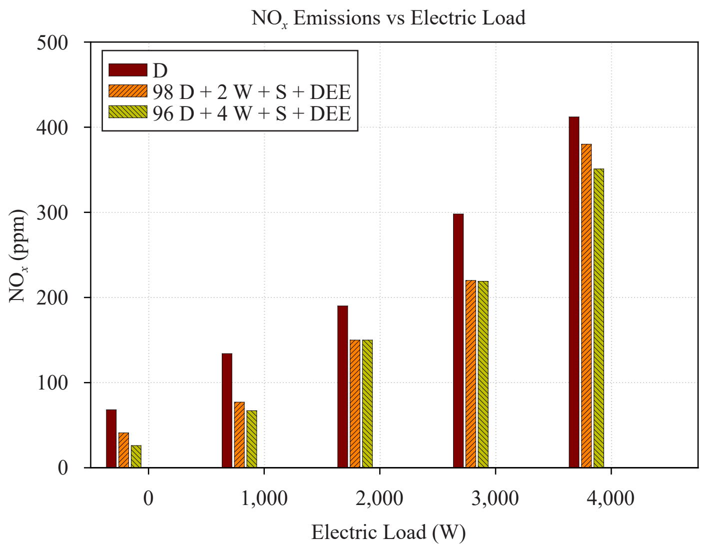

Figure 4. NO_x emission variation of diesel and water blended diesel fuels

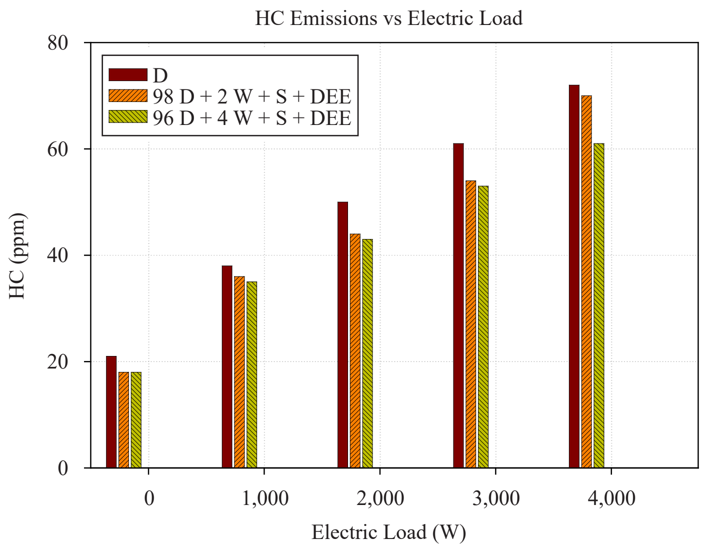

Figure 5. HC emission variation of diesel and water blended diesel fuels

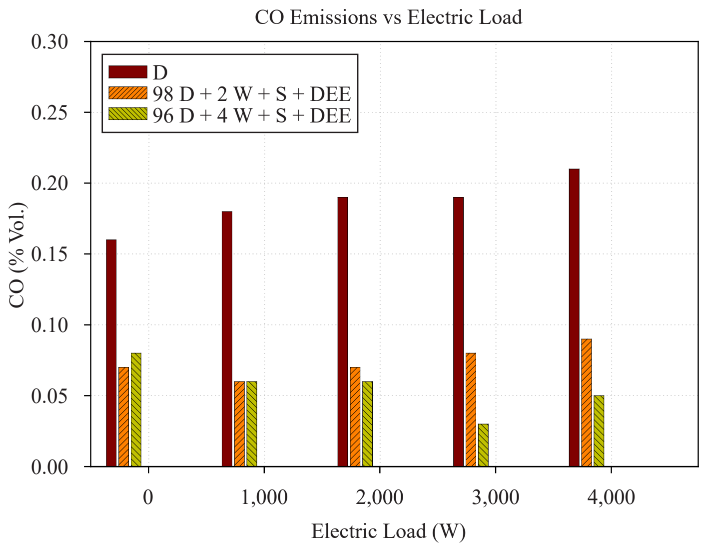

Figure 6. CO emission variation of diesel and water blended diesel fuels

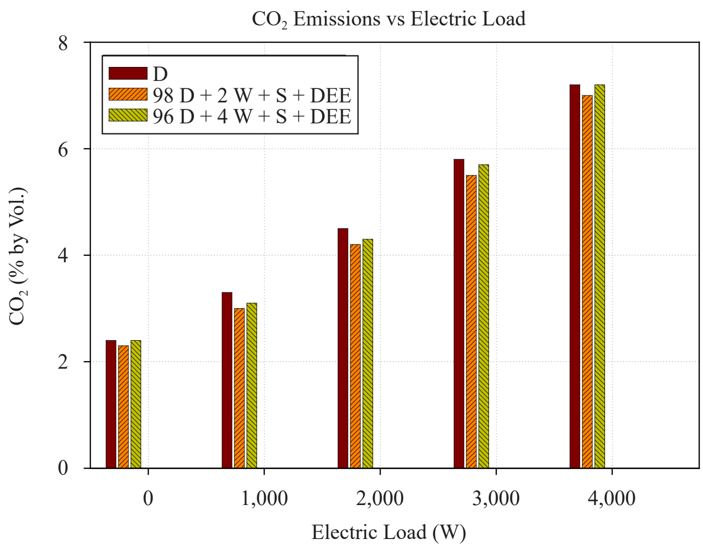

Figure 7. CO_2 emission variation of diesel and water blended diesel fuels

5. Conclusions

With fortitude to enhance the performance feature and reduce emissions from a diesel engine generator without any major modification, the current study was carried out on blending DEE and water with normal diesel fuel methodically. The following conclusions were drawn:

The stability of the water mixed diesel fuels (98D2WSDEE and 96D4WSDEE) were more than fifteen days under idle conditions.

There was no uncharacteristic noise or starting difficulty during the whole experimentation using DEE and water mixed diesel fuels.

DEE + Water mixed diesel fuels have extensively amended the working facets of the diesel engine generator.

At all the loads, the monoxides of carbon and oxides of nitrogen of the DEE + water mixed diesel fuels were overwhelmingly reduced. At the full load (4,000 W), the level of NO_x emissions for the normal diesel was 412 ppm;

whereas it was 380 ppm and 351 ppm for the 98D2WSDEE and 96D4WSDEE fuels respectively.

Overall, it is established that 4% of water DEE blended with diesel fuel has the potentiality to boost the working attributes of diesel engine generator.

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Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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