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Experimental Assessment to Reduce Emission of Compression Ignition Engine via Diesel/biodiesel/water Blends

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Introduction and background

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Air pollution dilemma

Greenhouse gases (GHGs) are now the top priority for the whole civilized world. [1].

Massive emissions are emitted by fossil fuels. Compression ignition engines (CI) emit a huge amount of carbon dioxides [2].

Diesel engines generally emit mono-carbon dioxide (CO), oxides of nitrogen (NOx), hydrocarbon content (HC), particulate matter (PM), and sulfur oxides (SOx) [4]. The PM and NOx emissions have a crucial impact on health [3]

Air pollution dilemma

Annual marine fuel usage ranged from around 250-325 million tons. in contrast, the average emissions yearly of SOx, NOx, and CO2 were 11.3, 20.9, and 1016 million tons [4].

Due to this, the International Maritime Organization (IMO), The UN organization in charge of marine emission reductions has established a target for global shipping of achieving a 50% decrease in emissions from 2008 to 2050 [5].

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Air pollution dilemma

The emission mitigation potential of alternative maritime fuels, such as natural gas, methanol, biofuels, hydrogen, and ammonia, Alternative marine fuels, have their potential to reduce emissions. The various decarbonization pathways are recommended in recent studies that have been reviewed [9].

Biofuels have a variety of sources of fuel produced by converting raw biomass or biomass waste into liquid or gaseous fuels. The three most promising biofuels for ships are hydro-treated vegetable oil (HVO), fatty acid methyl esters (FAMEs), and liquid biogas (LBG) [10].

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Research Gap

The new retrofitting of the CI engine, Exhaust after treatment methods such as EGR, or new green fuels is still not cost-effective and is a burden on the owners and governments.

Utilizing the water blending to diesel and biodiesel is a motivating point for complying with the Low Combustion Chamber (LCT) concept for better engine emission.

But it should be employed without compromising the engine performance.

Literature Review

The authors [12] participated in the LCT concept evaluation by using straight-run naphtha as a low-cost addition to diesel and diesel/biodiesel fuels. The results suggest that the diesel/straight-run naphtha blends reduce NOx by 47-23% while consuming 7.5% less fuel than the fossil diesel experiment, however, the biodiesel/diesel/naphtha experiment remains disputable due to increased brake-specific fuel consumption (bsfc) and kicking-off synchro motor at high loads.

According to Peng et al. [15], the most effective technique is the water-diesel emulsion (WDE) strategy, which can decrease NOx emissions from diesel engines without altering the engine's design.

Literature Review

Amirnordin et al. [16], found that water in biodiesel blends enhances fuel atomization because water has a lower boiling temperature than fuel molecules. Hence, water molecules evaporate first, causing a burst of finer fuel droplets that create a microexplosion phenomenon. This phenomenon causes a shorter fuel evaporation time, an enhanced air-fuel mixing process, and an enhancer for combustion according to Khond and Kriplani [17].

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Research scope

This study focuses on the affections of low percentages of water on diesel and diesel/biodiesel fuels with an experimental series without adding surfactant to the blends. An ultrasonication blender was used to acquire homogeneous blends for characterizing the performance and emission of CI engines under various loads.

The influence of changes in physicochemical parameters for the employed blends was emphasized to relate them with the observed findings. The ideal blend is identified in the findings.

MATERIAL AND METHOD

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1. Test Fuels

Water was employed as a binary and ternary additive in the current study together with two different fuel types: fossil diesel and diesel/biodiesel blend with a 30% by volume for biodiesel. The local station that provides the diesel, where the biodiesel was produced from WCO, Alexandria Company for Petroleum Additives (ACPA) manufactures, a reputable petrochemical company. The water was obtained from the laboratory tap. Table (1) shows the characteristics of the base fuels.

Table 1. Diesel and biodiesel Physicochemical Properties [21–23].

Properties	Bio-diesel	Diesel	Method
Density at 23 °C, Kg/m3	882	839	(ASTM-D-1298)
Auto-ignition Temperature, °C	225	246	(ASTM-E-659)
Net-heat Value, MJ/Kg	37.1	43.1	(ASTM-D-240)
Kinematic Viscosity at 40 °C, CSt	4.6	3.8	(ASTM-D-445)
Free Methanol	0.5	-	%wt.
Ester Content	93	-	%wt.

Diesel/water and diesel/biodiesel/water blends percentage

Tested Fuel	HV (MJ/kg)	Density (kg/m3)	Kinematic Viscosity (CSt)
D100	43.1	839	3.8
B100	37.1	882	4.6
B30	41.24	851.9	4.03
Water	--	995.5	1
W1	42.57	840.57	3.84
W3	41.5	843.7	3.92
W5	40.45	846.83	4.00
B30W1	40.74	853.32	4.33
B30W3	39.77	856.08	4.76
B30W5	38.85	858.74	5.82

An ultrasonication blender has been used for diesel/water and diesel/biodiesel/water blends

(a) (b)

Figure (2) (a) Diesel and (b) biodiesel emulsion blending via ultrasonication blender

1. Experimental test rig

A single-cylinder (HATZ-1B30-2), a 4-stroke engine with direct injection, is used for performing the experiments. The facility is set up at the energy resources laboratory (E-JUST), and its specification is mentioned [24]. Experiments were performed in a constant engine revolution at 2000 rpm and with different engine loads of 0, 3, 6, 9, and 12 Nm.

The Synchronous motor simulated the experimental loads on the CI engine. The emission analyzer was used in the Bacharach ECA 450 experiment model to measure NOx and CO emissions. The data acquisition captured the engine's parameters during each experiment and recorded it separately. The engine photo and diagram are shown in Fig. (1).

Rig-up setup (HATZ-1B30-2)

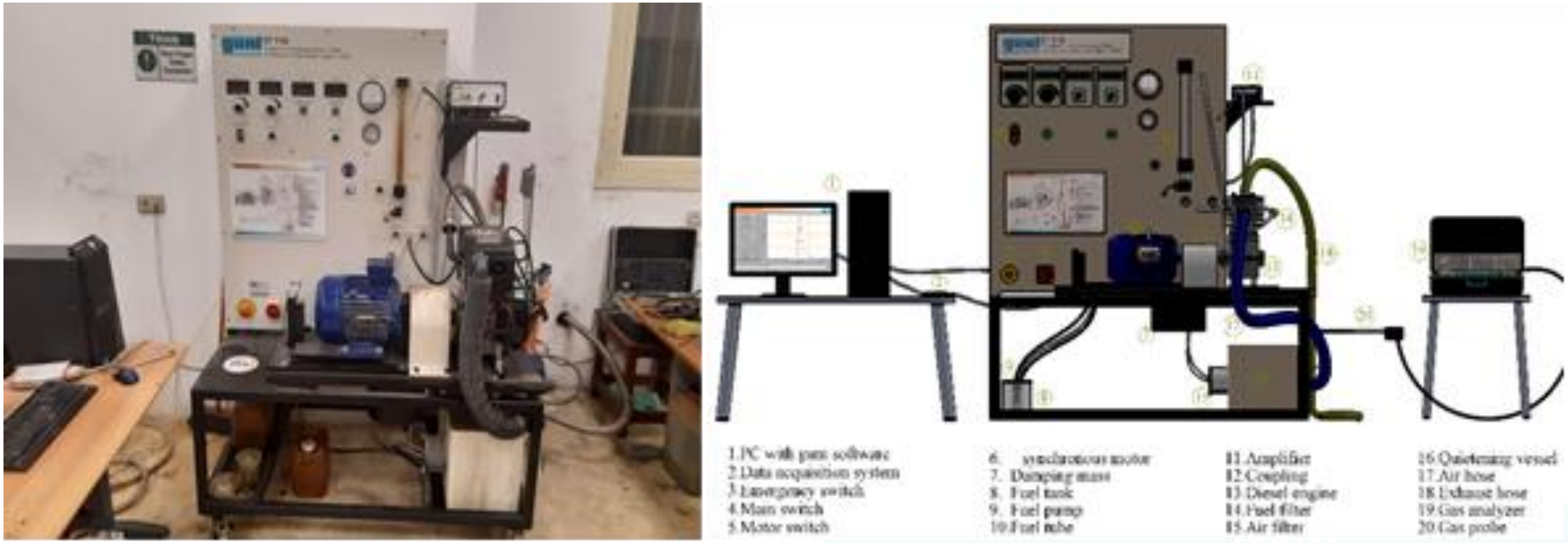

Figure 1: Test Rig and Control Unit Diagram

Results and Discussion

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Engine Performance

(brake-specific fuel consumption)

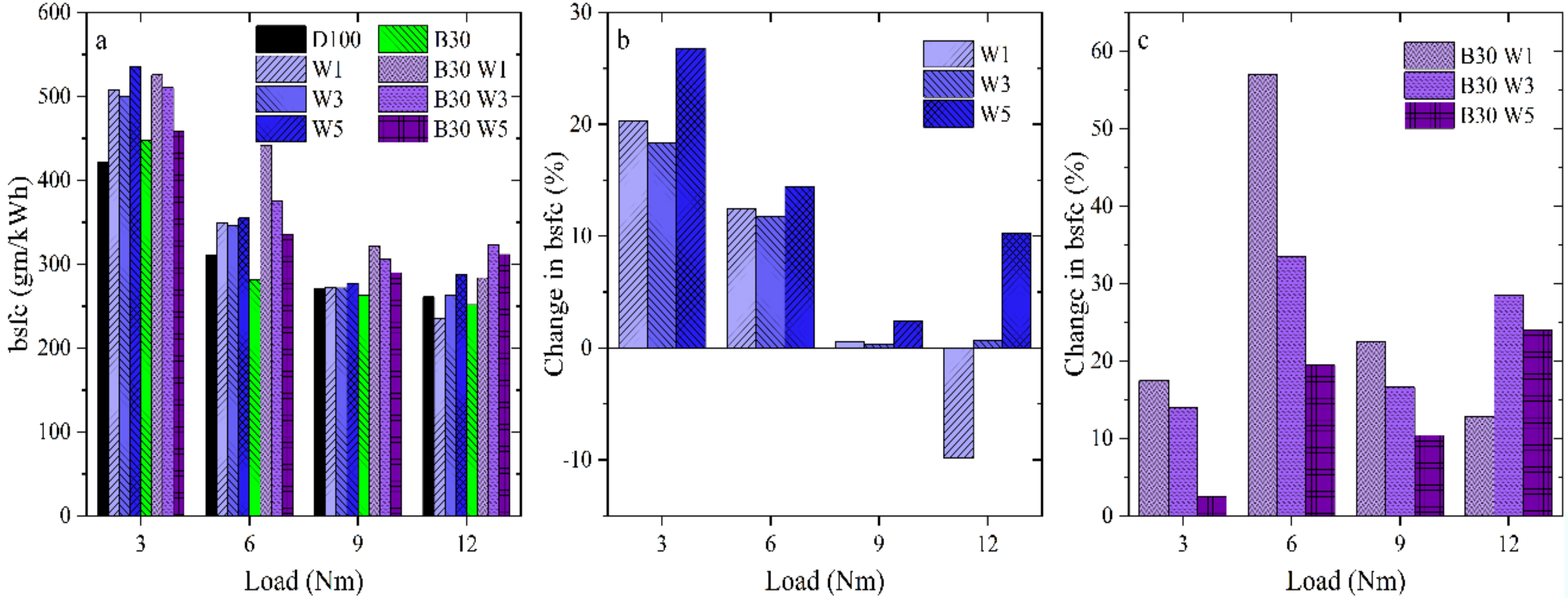

Figure 2: (a) bsfc variance for blends at experiment loads at 2000 rpm, (b) bsfc change percent for W1, W3, W5 relative to D100, (c) bsfc change percentage for B30W1, B30W3, B30W5 relative to B30.

Combustion Characteristics

in-cylinder pressures (bar) versus the crank angle (degree).

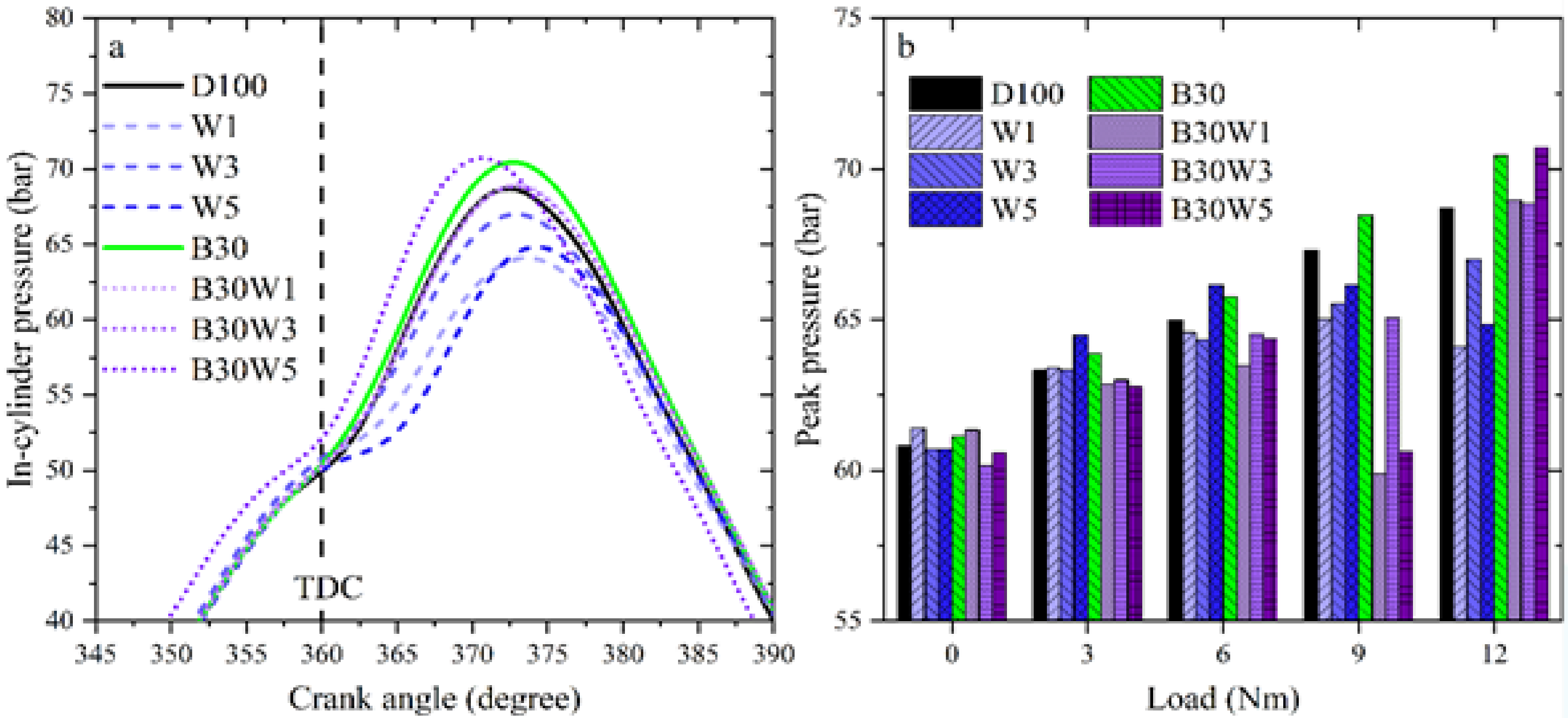

Figure 3: (a) In-cylinder Pressure vs. °CA for the Test blends at load 12Nm and 2000 rpm, and (b) Peak Pressure for Fuel Blends at various loads

Combustion Characteristics

The heat release versus the crank angle degree & and the 50% heat release at CA

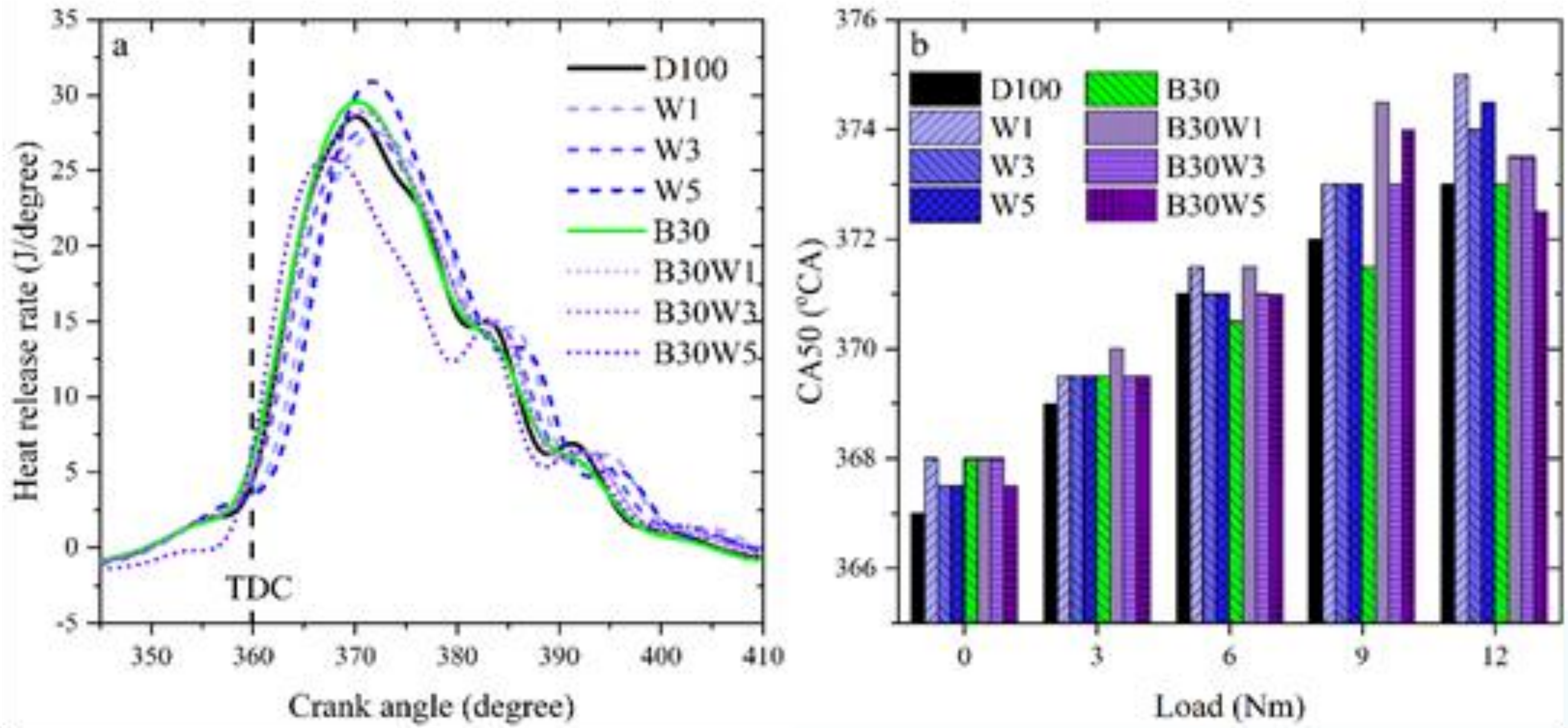

Figure 4: (a) Net heat release rate vs. crank angle for fuel blends at 12 Nm and 2000 rpm, and (b) CA50 angles vs. load for tested fuel blends at various loads.

Emission Characteristic

NOx and CO emissions Vs. Engine Loads

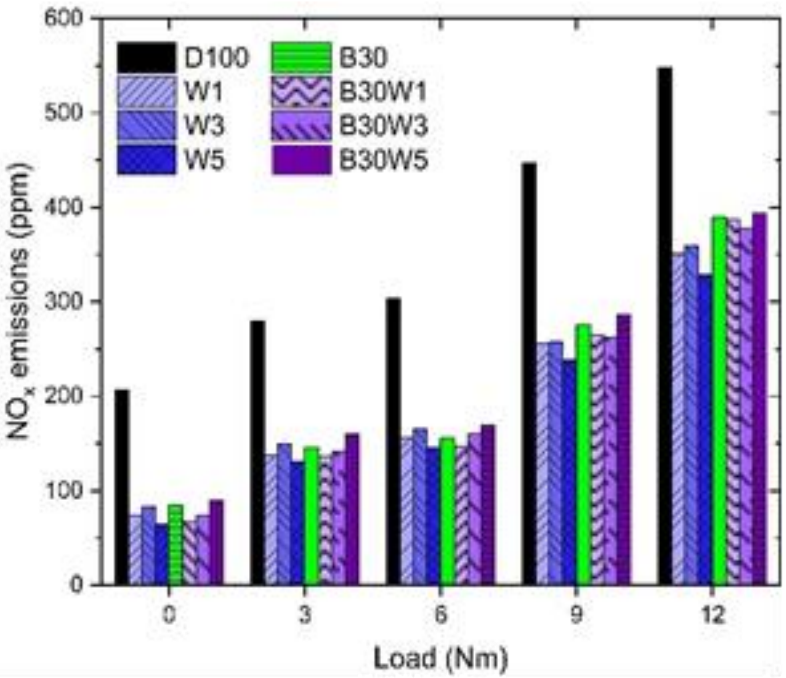

Figure 5. NO_x emissions varied among all tested fuels at (0-12) Nm at 2000 rpm.

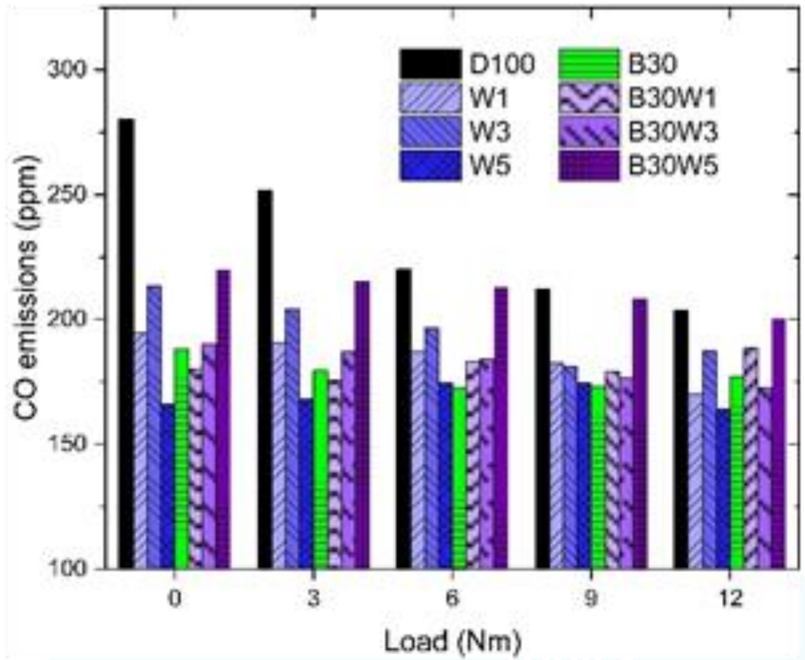

Figure 6. CO emissions varied among all tested fuels at (0-12) Nm at 2000 rpm

Uncertainty analysis

Table 2. The measured parameters' extent, precision, accuracy, and total uncertainty.

Exhaust gas analyzer parameters	Extent	Precision	Instrument uncertainty (Us)	Random Uncertainty (U_R)	Total Uncertainty (U_t)
CO (ppm)	0 - 4000 ppm	1 ppm	(± 10 ppm) or ± 5% of Value	± 1.16 %	± 5.13%
NOx (ppm)	0 - 4000 ppm	1 ppm	(± 5 ppm) or ± 5 % of Value	± 0.43 %	± 5.02%
Pressure transducer (bar)	0-250	_	± 1% of Value	± 1%	± 1.41%
Crank angle encoder (degree)	0-720	0.5	± 0.5°	± 0.3%	± 0.58%
Torque indicator (Nm)	0-50	0.1	±1% of Value	± 0.38%	± 1.07%
Fuel burette (cm3)	153	_	± 0.2 cm3	± 4%	± 4.06%
Speed sensor (rpm)	0-10000	1 rpm	± 5 rpm	± 0.1%	± 0.27%

Conclusion

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The bsfc reduction of 9% for the W1 blend at 80% of the full load relative to D100

the approximate bsfc value of W1 and W3 at 60% of the engine's full load relates to D100

W1 declined 36% of NOx emission with the best compromising of CO emission with a diminishing value of 17.5% related to D100.

Diesel Water Blends

Biodiesel Water Blends

higher bsfc at all loads for all blends

Biodiesel/water blends reflect a negligible effect for NOx reduction with a slight increase in CO emission at 80% relative to the B30 blend.

The B30 is considered an optimum blend which acquired NOx emission reduction of 30% to 50%

And better complete combustion at 80% load by lesser percent of CO emission of 23% relates to D100

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