Performance And Exhaust Emission Characteristics Investigation of Compression Ignition Engine Fuelled With Microalgae Biodiesel And Its Diesel Blends

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Abstract

Biofuels extracted from plant biomass can be used as fuel in CI engines to lower a hazardous atmospheric pollutant and mitigate climate risks. Furthermore, its implementation is hampered by inevitable obstacles such as feed stocks and the crop area required for their cultivation, leading to a lack of agricultural land for the expansion of food yields. Despite this, microalgae have been discovered to be the most competent and unwavering source of biodiesel due to their distinguishing characteristics of being non-eatable and requiring no cropland for cultivation. The objectives of this paper was to look into the potential of a novel, formerly underappreciated biodiesel from microalgae species which could be used as a fuel substitute.

Transesterification is being used to extract the biodiesel. Microalgae are blended with petroleum diesel in percentage to create Microalgae Blends (MAB) as needed for experimentation. The impact of biodiesel on performance as well as exhaust emission attributes of a 1-cylinder diesel engine was experimentally studied. Compared to petroleum diesel, different blend of Microalgae biodiesel showed a decline in torque and hence brake power, resulting in an average fall of 7.14 percent in brake thermal efficiency and 11.54 percent increase in brake specific fuel consumption. There were wide differences in exhaust emission characteristics, including carbon monoxide and hydrocarbon, as the blend ratio in diesel increased. Moreover, nitrogen oxides and carbon dioxides increase in all algae biodiesel blends, but they're still within the acceptable range of petroleum diesel.

Introduction

The current state of non - renewable fossil fuels seems to be inherently unpredictable, yet somehow the global economy is reliant on them. In this circumstance, the exhaustion of petroleum derivatives, coupled with an increase in cost, as well as a worrisome increase in levels of contamination, is a real catastrophe for the general public. Multiple potential biodiesel alternatives have already been identified for helping in this issue balance, but none have been touted as a complete replacement for diesel due to their unfavorable physiochemical characteristics. Furthermore, a huge number of vehicles are sold on the streets on a regular basis. This will put further strain on the petroleum industry, as well as raise environmental risks. To combat the exhaustion of petroleum products and the spread of contamination, it is now urgent to provide different kinds of alternative fuel (BP Statistical Review 2019). Biodiesel extracted from microalgae will seems to be the promising alternative to answer this issue.

Material And Methods

Algae absorb carbon dioxide from the environment and replenish it with ambient oxygen using photosynthetic mechanisms. Algal biodiesel plants are setup close to energy generating units, which produce loads of carbon dioxide. Reusing carbon di-oxide reduces pollution in the environment. Furthermore, algae can grow in any location, under any atmospheric circumstances, without interfering with the acquisition of land for food crops. The oil output per acre land varies from 19000 to 57000 liters per acre among thousands of different algal species. Because of this oil concentration, algae are a better candidate for biodiesel production.

Adopting the standard procedure suggested by American Society for Testing and Materials (ASTM), raw algae was converted in to algae methyl ester (biodiesel) by means of widely used transesterification process. Transesterification reduces the viscosity of algae oil considerably and enhance the combustion properties required for complete combustion in association with inbuilt oxygen content of algae. Afterwards the blends of biodiesel were prepared on volumetric basis for experimentations. The physiochemical properties of blends were find out and that are within the acceptable limits of ASTM.

Experiments were conducted on a 1- cylinder engine set up coupled with an eddy current dynamometer. The setup allows for compression ratio change ranging from 12.5:1 to 18:5. The detailed specifications of experimental test rig were summarized in Table 1. All of the experiments were carried out as per normal operating procedures.

Table 1
Technical specification of Experimental Test Rig

Parameter	**Specification**
Form	4-Stroke
Total No. of cylinder	01
Bore Diameter (m)	0.0875
Stroke Length (m)	0.11
Cubic capacity (cm^3)	661
CR	17.5:1
Topmost Pressure	77.5 kg per square cm
Maximum RPM	2000
Minimum idle RPM	750
Minimum. operational RPM	1200

Figure 3 shows a MARS Multi Gas Analyzer (Model: MN-05, ARAI Approved) being used to monitor emission parameters. Table 2 shows the measurement range as well as the accuracy of the Multi Gas Analyzer.

Table 2
Measurement range resolution and accuracy of multi gas analyzer

Parameter	Range	Accuracy
CO	0 to 9.99% Vol.	0.001% Vol.
CO2	0 to 20% Vol.	0.01% Vol.
HC (propane)	0 to 15000 ppm	01 ppm
O2	0 to 25% Vol.	0.1% Vol.
NOx	0 to 5000 ppm	1 ppm Vol.
Engine RPM	500 to 6000 rpm	1 rpm
Lambda	0.200 to 2.000%	0.001

Results And Discussion

3.1. Performance Characteristics

Basic engine performance metrics such as BTE and BSFC were determined in this experiment for blends of microalgae biodiesel and compared with results obtained using petro diesel fuel.

Figure 4 depicted the fluctuation in brake thermal efficiency versus engine load. As compare to petro diesel fuel mode, brake thermal efficiency decreases with fuel blends type as the load on the engine alters plus increases with the engine load rises. The specific fuel consumption increases as the calorific value declines in the microalgae fuel blends mode, affecting the brake thermal efficiency. Additionally, when the percentage of blended fuel increases, the fuel's calorific value drops, leading to decreased rate of heat release and, ultimately, a fall in the engine's brake thermal efficiency (Kalsi SS et.al. 2017). In contrast to diesel fuel, there is a 2.41 percent reduction in brake thermal efficiency for MAB10 and a 7.14 percent drop in brake thermal efficiency for MAB50. BTE rises as engine load rises, and previous study has found similar trends. (Elsanusi OA et.al. 2017; Datta A et.al.2017; Srihari S et.al. 2017; Can O et.al.2017).

BSFC is influenced directly by the test fuel's heating value. The impact of heating value in fuel complete combustion cannot be overstated. Because biodiesel and their blends bears a lower heating value, they have a direct impact on brake specific fuel consumption. Figure 5 depicts the BSFC's behavioral variability as a function of the engine's loading. The plot clearly shows that BSFC is the lowest-cost diesel fuel, followed by all microalgae biodiesel mixes at such loads. When compared to diesel fuel, the BSFC of MAB10 enhanced by 3.43 percent and MAB50 increased by 11.54 percent. Figure 5 shows that BSFC decreases with greater load for each microalgae biodiesel blend because combustion efficiency increases. In a cited study (Srihari S et.al. 2017; Can O et.al.2017; Gorji RM et.al. 2017), a similar trend of result was seen.

3.2. Emission Characteristics

In this experimentation for microalgae biodiesel blends and diesel fuel, engine exhaust emission characteristics such as CO_2, NO_X, HC and CO gas emissions were determined in this experiment in accord with various loads placed on the test engine and compared to petroleum diesel fuel.

The elements that determine CO_2 emissions from engine exhaust include viscosity, atomization process, CR, oxygen, engine rpm, and so on (Celik M et.al. 2017; Rahman SMA et.al. 2013; Gharehghani A et.al.2017; Muralidharan K, et.al. 2011). Figure 6 shows the variance in CO_2 emissions as a function of engine loading for studied fuels: petroleum diesel, MAB10, MAB20, MAB30, MAB40, and MAB50. In comparison to diesel, the CO_2 content of microalgae biodiesel blends was found to be greater.

The temperature of combustion, the oxygen concentration of the fuel along with the actual space of the combustion zone were the elements that directly influence NO_X emissions (Zehra S et.al.2014). Different elements that influence NO_X exhaust emissions include stoichiometry, temperature of flame, delay in ignition, fatty acid composition, heat removal rate (HRR), premixing, cetane number, injection timing as well as thermo-physical properties of the fuel (Rajak U et.al. 2018; Shrivastava P et.al. 2019; Subhaschandra ST et.al.2019). In accordance with engine loads, Fig. 07 depicts NOX exhaust emission fluctuations for microalgae biodiesel blends and petroleum diesel fuel. It has been witnessed that when the load on engine increases, so does NO_X exhaust output increases. In comparison to petroleum diesel fuel, NOX emissions from Microalgae Biodiesel mixes were thought to be higher.

Figure 8 shows how hydrocarbon exhaust emissions vary depending on engine load for all microalgae biodiesel blends as well as petroleum diesel. MAB10 Microalgae Biodiesel Blends reduced HC emissions by 9.2 percent compared to diesel fuel, 20.58 percent compared to MAB20, 29.62 percent compared to MAB30, 23.84 percent compared to MAB40, and 13 percent compared to MAB50 Microalgae Biodiesel Blends. Figure 8 shows how increasing the blending % in diesel fuel affects HC emissions. This could be linked to biodiesel blends' higher kinetic viscosity, which slows fuel atomization and hence reduces HC emissions (Çelikten I. et.al 2012).

Figure 9 depicts the changes in CO exhaust emissions for all tested microalgae biodiesel blends and petroleum diesel fuel under various engine loading levels. The CO exhaust emission is least for increasing engine loading for all the fuels evaluated, according to the observations.

Biodiesel and its blends are oxygenated fuels that allow for complete combustion which allows conversion of CO to CO_2 molecules, resulting in significant decline in CO emissions as compared to petro diesel (Çelikten I. et.al 2012). The average decline in CO emission was 7.7% for MAB10, 16.8% for MAB20, 12.60 percent for MAB30, 13.30 percent for MAB40, and 14.54 percent for MAB50 when compared to diesel fuel.

Conclusion

Following points were concluded from the experimental work carried out

1. 7.14 percent reduction in BTE as compared to petro diesel fuel for blends of microalgae biodiesel.

2. In comparison to petroleum diesel, BSFC was shown to be higher in all microalgae biodiesel blends.

3. It has been found that a microalgae biodiesel blend raises CO_2 emissions, but otherwise is compatible with diesel fuel.

4. It has been found that as engine load increases, NO_X exhaust output increases as well. However, by utilizing cutting-edge technology such as engine operating parameters and exhaust gas control, this problem can be successfully addressed.

5. For all microalgae biodiesel blends, the decrease in HC as well as CO emissions when compared to petro diesel fuel.

According to the results of the aforementioned experiment, microalgae biodiesel blend MAB30 possesses physiochemical qualities similar to petro diesel. It achieves the best results in terms of performance and exhaust emission characteristics.

Abbreviations

ASTM American Society for Testing and Materials standards

BP Brake power

BSFC Brake specific fuel consumption

BTE Brake thermal efficiency

CO Carbon Monoxide

CO_2 Carbon dioxide

HC Hydrocarbons

MAB10 Biodiesel blends (10 % Algae + 90% Petro-diesel)

MAB20 Biodiesel blends (20 % Algae + 80% Petro-diesel)

MAB30 Biodiesel blends (30 % Algae + 70% Petro-diesel)

MAB40 Biodiesel blends (40 % Algae + 60% Petro-diesel)

MAB50 Biodiesel blends (50 % Algae + 50% Petro-diesel)

NOx Nitrogen Oxides

Declarations

Ethical Approval

The submitted work is original and not have been published elsewhere in any form or language. This manuscript is presented in “International Conference on Advances in Sustainable Research for Energy and Environmental Management (ASREEM-2021) on 06th August 2021.The conference is organised by Department of Chemical Engineering SVNIT Surat.

Consent to Participate

Not applicable

Consent to Publish

Not applicable

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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.

Availability of data and material

The data that supports the findings of this study are available within the article and proper reference were provided.

Credit authorship contribution statement

Bhojraj Kale: Data curation, Formal analysis, Investigation, Methodology, Resources, Software, Validation, Visualization, Writing - original draft.

Sewan Das Patle: Conceptualization, Data curation, Visualization, Project administration, Supervision, Writing – review & editing.

Vijay Khawale : Plagiarism scan, Data curation, Visualization, Writing - review & editing.

Sandeep Lutade:, Data curation, Visualization, Writing - review & editing.

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.

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Figures

(a) (b)

Figure 1

(a) Raw Algae Collection (b) dried Algae

Figure 2

Experimental Test Rig

Figure 3

Multi Gas analyser (MARS, Model: MN-05)

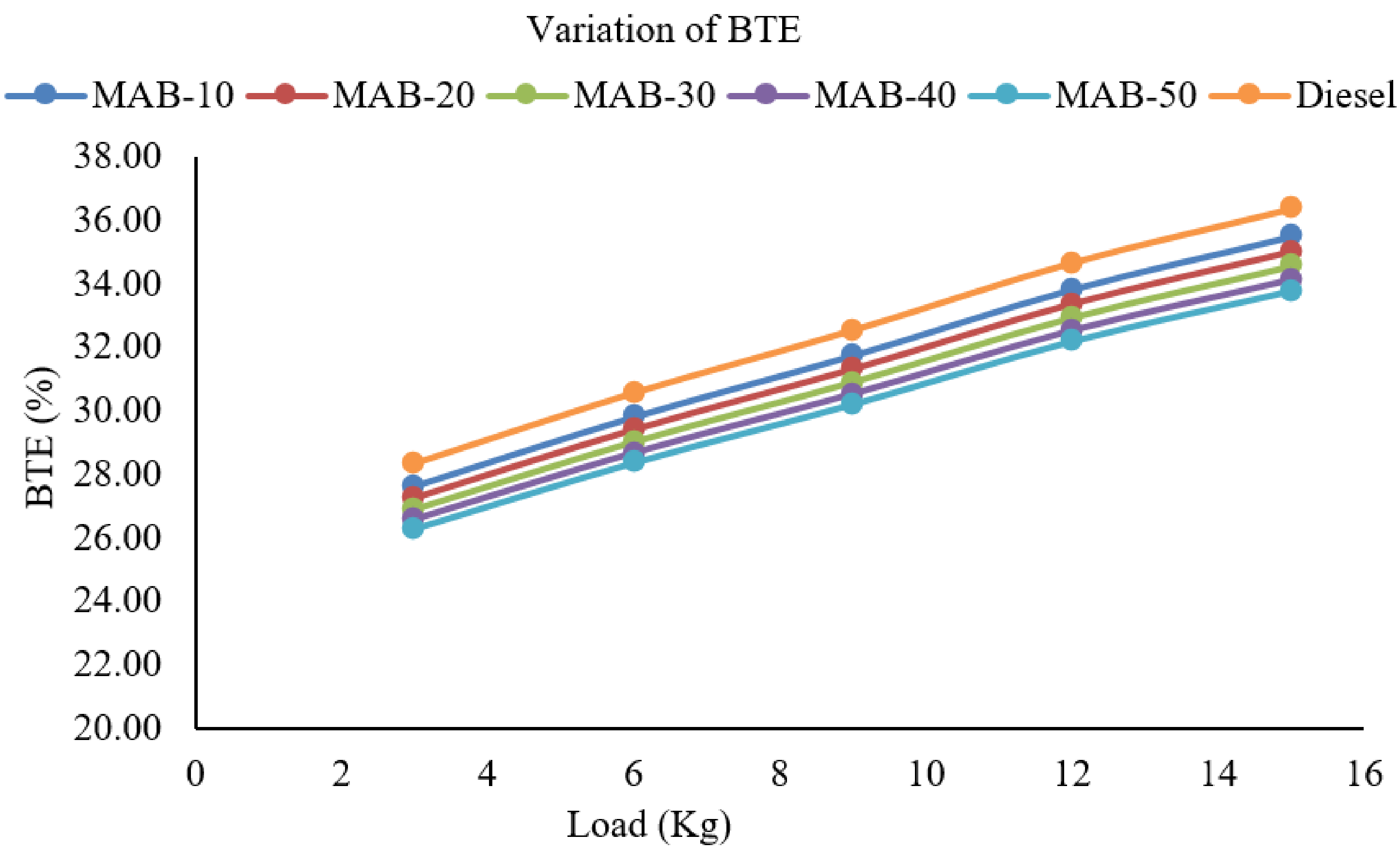

Figure 4

Variance in brake thermal efficiency as a function of load.

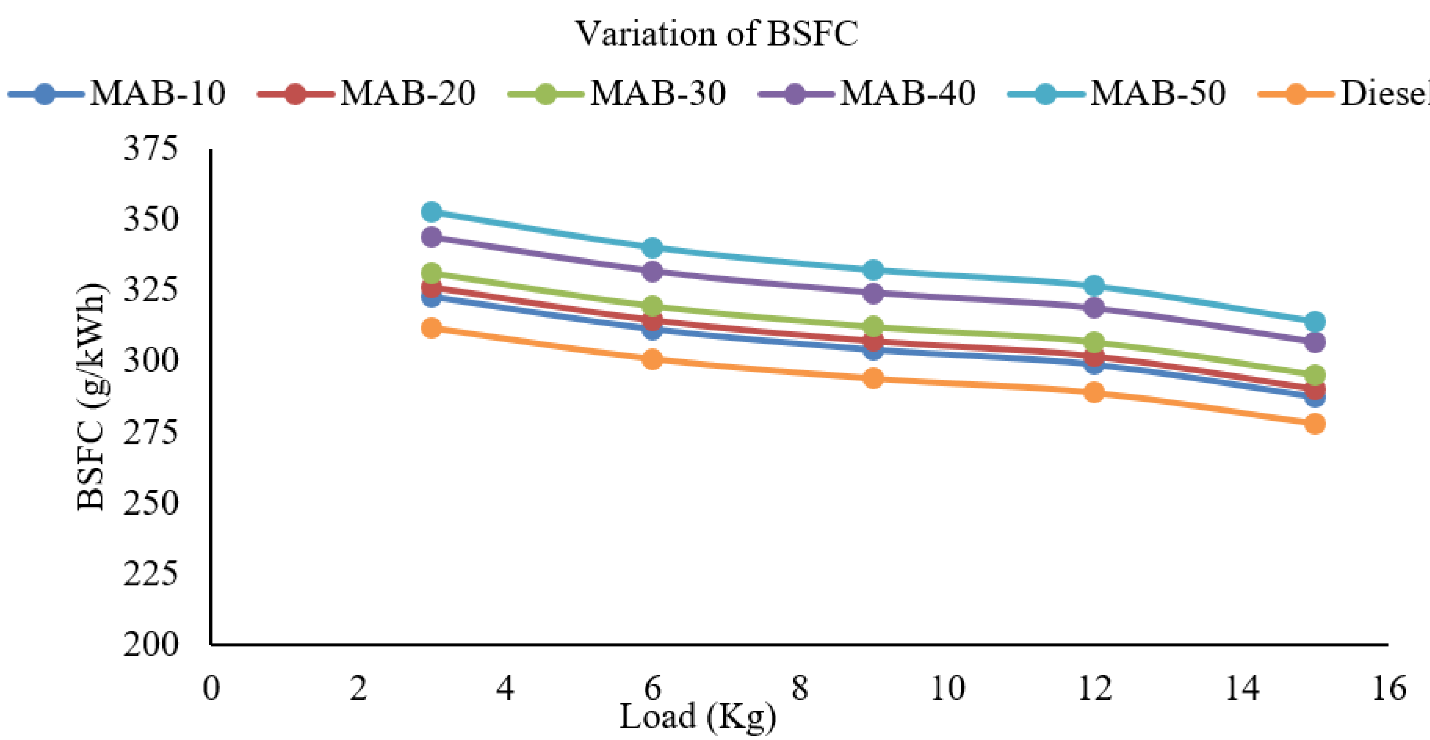

Figure 5

Variance in brake specific fuel consumption as a function of load.

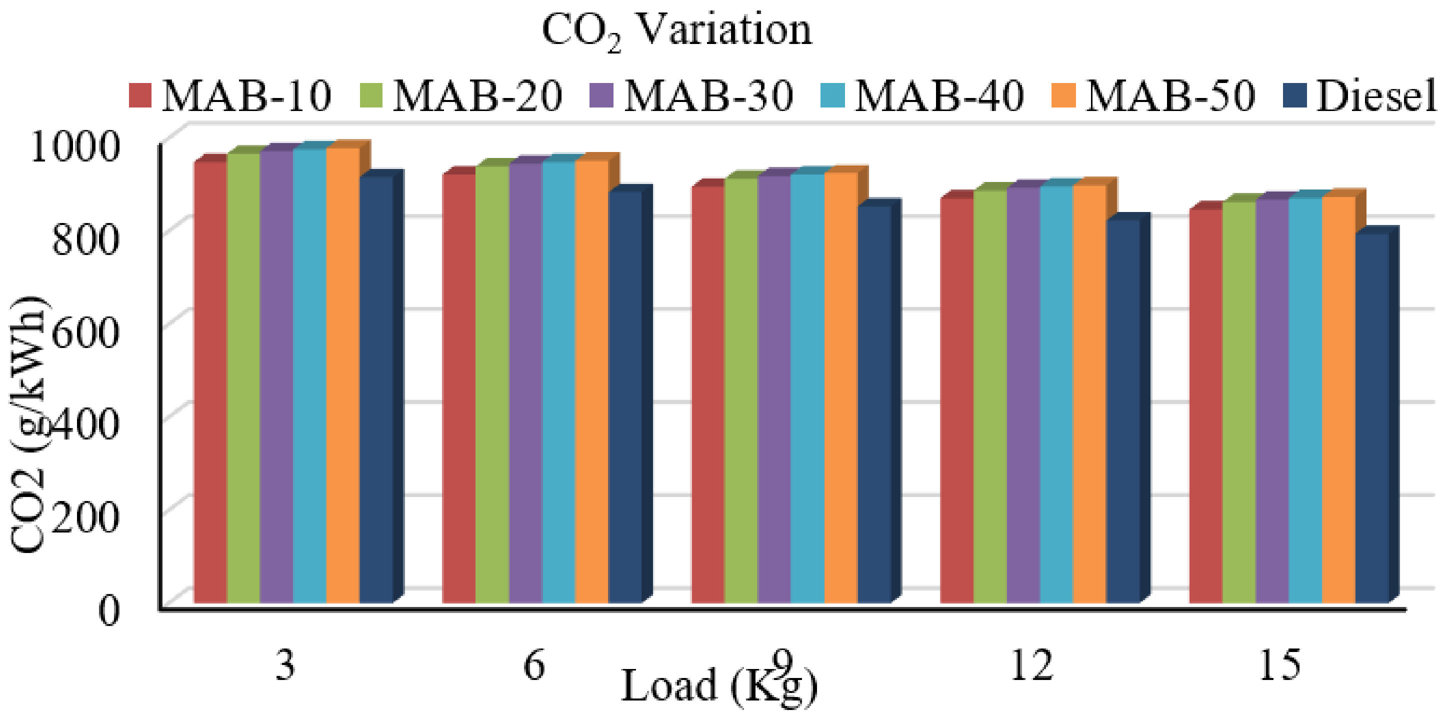

Figure 6

Variance in CO2 emission as a function of load.

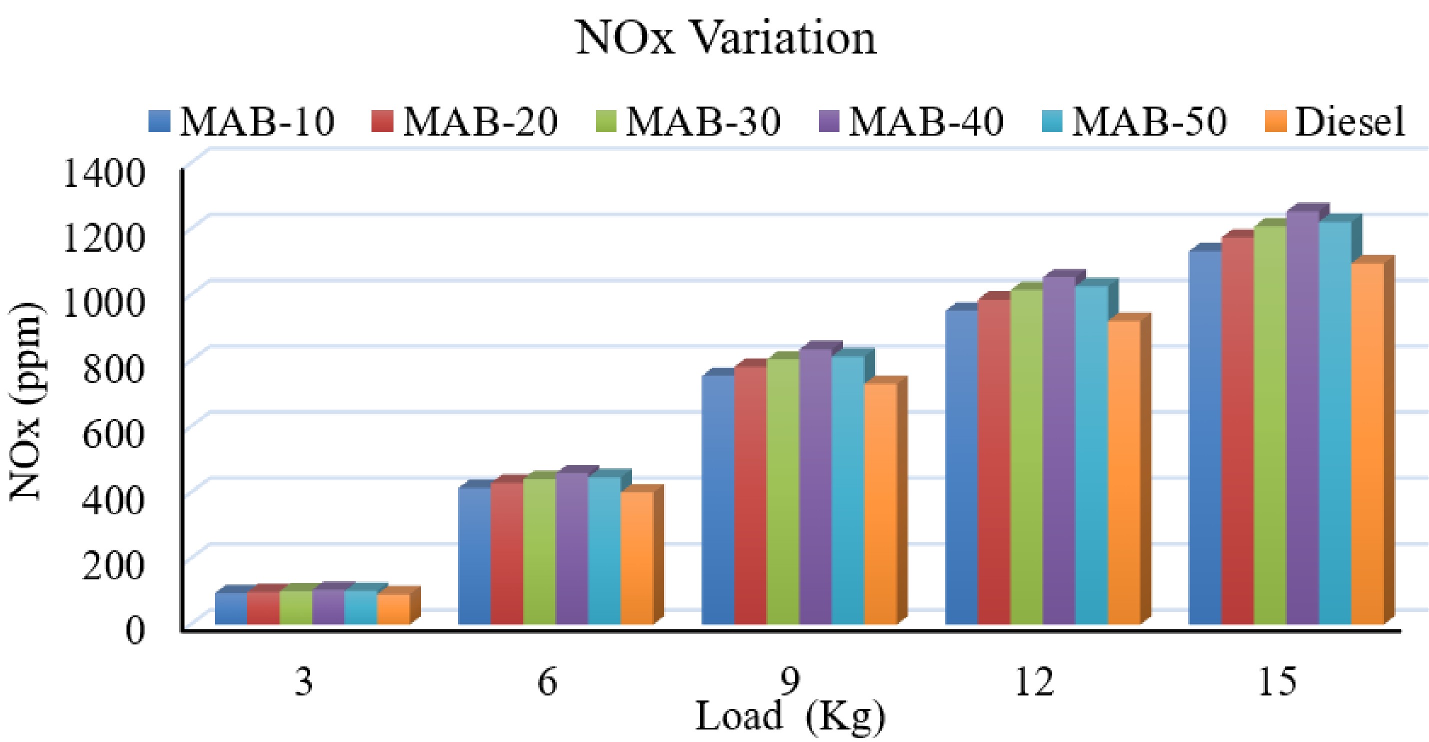

Figure 7

Variance in NOx emission as a function of load.

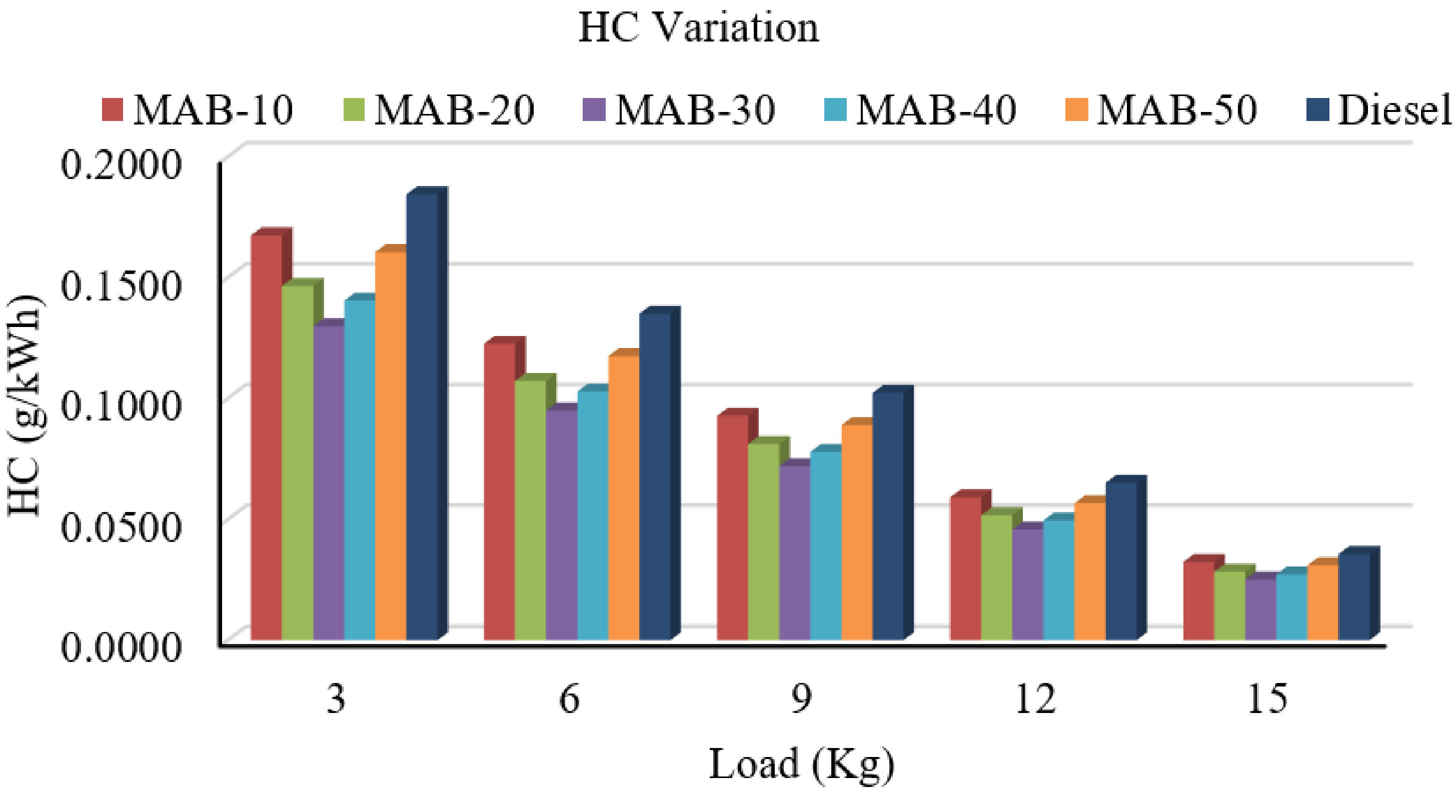

Figure 8

Variance in hydrocarbons emission as a function of load.

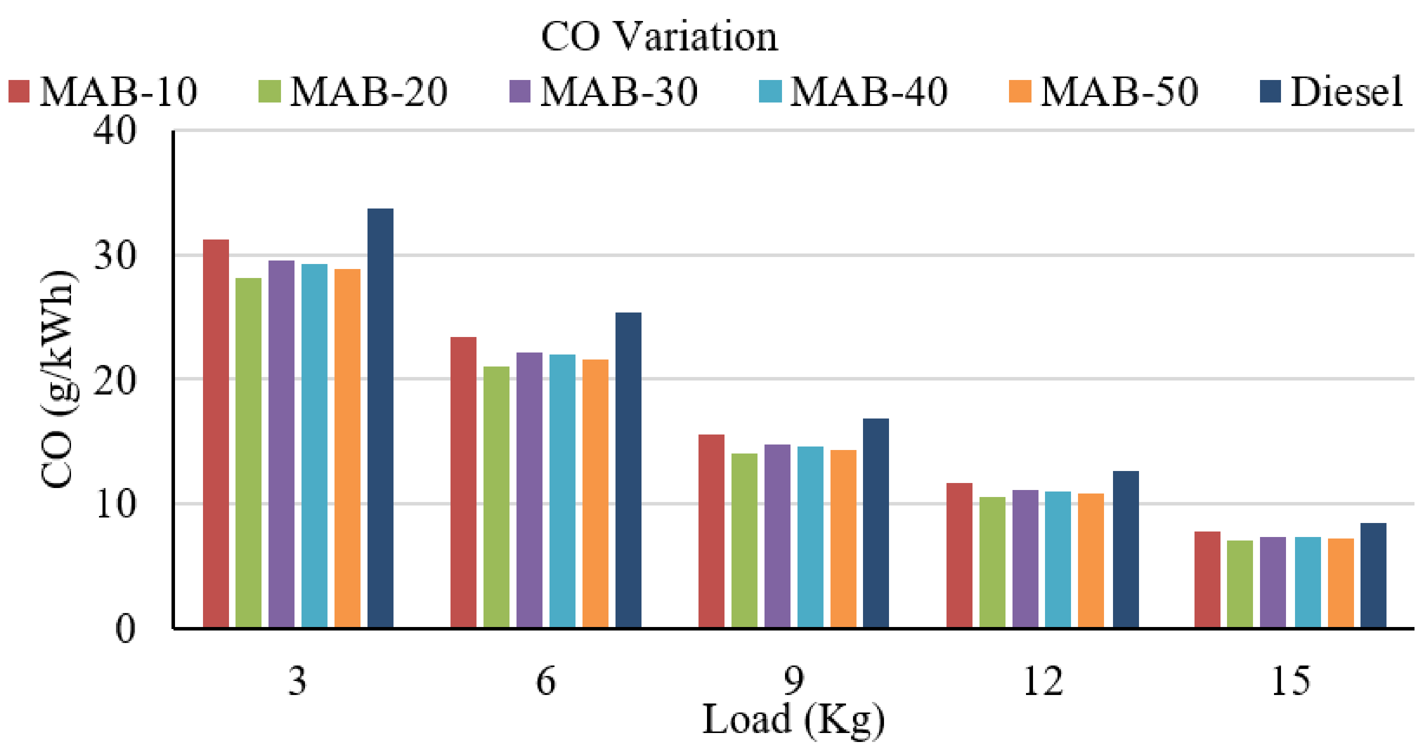

Figure 9

Variance in CO emission as a function of load.