Reduction of Emissions in Diesel Engine using Blended Diesel with Edible Bran Oil

Aditya Singh
National Institute of Technology
Dr.Shambhunath Barman
National Institute of Technology
P Mondal
Indian Institute of Engineering Science and Technology
N Barman (nilkantajdvu@yahoo.com)
Jadavpur University

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Abstract

Compare to the other internal combustion engines, the Diesel engine contributes a considerable part in air pollution; especially by emission of sulfur oxides (SOx) along with NOx, CO, and HC, those have a significant effect on the environment as well as on the human health. In concern to the fact, maintaining of the emissions out of diesel engines into the environment is mandatory; accordingly, a standard for emission regulation is set stringently from the BS-IV to BS-VI in this decade. Under this background, it is essential to look for an alternative method to reduce the emissions. Blending of biofuel with diesel is one of the suitable methods. On the track, most of the research works considered neem and jatropha oil as biofuel for blending. However, use of rice bran oil (RBO) is an interesting option, and rarely considered as a biofuel for the engines. In the present work, thus, the emission of pollutants and performance of a single cylinder Diesel engine with variable compression ratio (VCR) facility, made of Kirloskar, are investigated experimentally powered using blending of rice bran oil (0%, 15% and 30%) with diesel under three suitable compression ratios. It is observed, out of the experimental results, that the emission of major pollutants is less compare to using of pure diesel, together with almost same power output, which is a significant outcome of the research. This work recommends blending of the rice bran oil up to a limit of 30% in diesel and the engine is to be operated at moderate load.

Introduction

Increase in population and urbanization forces the civilization to consume more fossil fuels in order to supply necessary and enough amount of energy for living. The emissions out of the combustion of these fossil fuels not only result in degradation of the air quality, but also create severe health issues to the human being in a long-term basis. The fact leads an attention of the researchers to think about usage of alternative fuels particularly in the automobile sector. Many research works reported in this direction for usage of the alternative fuels, either in solo or blended manner. Among various biodiesels, rice bran oil (RBO) attracted a great deal of attention as an alternative fuel in the form of blender due to low emissions on combustion and easily available in the market. Some of the major research works on usage of RBO and related works are presented here. Hoang *et al.* [1] presented evolution of the brake thermal efficiency (BTE) and brake specific fuel consumption (BSFC) using RBO as a blender. Dwivedi *et al.* [2] concluded on conducting experiments that the excess blending of biodiesel in the primary fuel leads a decrease in engine power output. This is probably due to less calorific value of the biodiesel compare to the diesel, also reported by Xue *et al.* [3]. In context to the emission of pollutants, Canaki and Garpen [4] presented that the biodiesel like soybeans oil reduces the exhaust gas emissions. Goga *et al.* [5] reported that increase in percentage (%) of biodiesel as the blender results in decrease of CO emission, due to presence of more oxygen particles at higher percentage (%) of the blender. Further, compare to the diesel, the biofuels have a high cetane number that leads a decrease to the ignition delay that results increase in pressure of the cylinder [6, 7]. The rich content of oxygen in the biofuels leads to the better combustion [8, 9] and decreases the carbon monoxide (CO), particulate matter (PM), and smoke [10, 11] in the emissions.

However, the NOx emission increases with use of the biofuels compare to conventional fuels [12, 13] due to high temperature inside of the engine cylinder [14].

The above review indicates that blending of biofuels in diesel is advantageous as the biofuels have a high cetane number and more oxygen content those lead to a better combustion and high-pressure rise [6–9] inside of the engine cylinder and reduces pollutants in the emissions. However, commercialization of this blending of biofuels in the primary fuels is till in developing stage, and an emerging research area in this decade. In addition, among the biofuels, the use of rice bran oil (RBO) is an interesting option due to its easy extraction and availability in the market, and that rarely used as the biofuel for blending with diesel. Accordingly, the present study aimed to carry out an analysis of the performance as well as emissions experimentally of a stationary Diesel engine facilitating the variable compression, made of Kirloskar, using diesel blended with rice bran oil (RBO) in accordance to establish the method of blending and accomplish to the standard of BS-VI emissions. The study involves reporting on major decisive parameters related to the performance such as brake power (BP), and brake thermal efficiency (BTE) as well as the emissions like NOx, SOx, COx and hydrocarbon (HC) etc. The study is conducted for three significant operating parameters: variable compression ratio (14–18), engine loading conditions (0–16 kg), and blending percentage (0–30%) of rice bran oil (RBO) with diesel towards establishing the utilization of rice bran oil (RBO) as a blender with diesel.

Experimental Setup

In order to conduct experiments, a single cylinder facilitating the variable compression and direct injection compression ignition (CI) diesel engine is considered; as it is available in the Workshop of NIT Sikkim. The schematic of the engine is shown in Fig. 1 along with pictorial view of engine head and measuring unit. The major specifications of the present engine are given in the Table-1. It is directly coupled with an eddy current dynamometer having a load capacity up to a maximum value of 16 kg to measure the brake power. The experiments are conducted at variable compression ratio (CR) in the range of 14–18. The fuel consumption rate is also measured for different load conditions and compression ratios (CRs).

The thermocouples (K-type) measure the temperature of exhaust gases. Subsequent, a gas analyzer measures the amount of different pollutants in the exhaust gas in order to analyse the emissions. Specifications of the gas analyser are presented in Table-2.

Table 1
Specifications of the diesel compression ignition (CI) engine

Description of the parameters	*Value*
Type of ignition	4-stroke and CI
Number of cylinders (*N*)	1
Manufacture of the engine	Kirloskar
Bore diameter of the engine (*D*)	87.50 mm
Stroke length of the engine (*L*)	110 mm
Connecting rod length of the engine (*l*)	234 mm
Dynamometer arm length (*S*)	185 mm
Power (P_o)	3.5 kW

Table 2
Specifications of present exhaust gas analyzer

Measuring Pollutant	*Range*
CO	0-15.5%
CO_2	0–21.00%
HC	0-20000 ppm
O_2	0–25%

Types Of Blended Fuels And Properties

The experiments are conducted using diesel and blended diesel with rice bran oil (RBO). The rice bran oil is extractable from the hard outer brown layer of rice. In this paper, two types of blended diesels are considered for experiments, namely B15 and B30. The fuel preparation is shown in Fig. 2. B15 and B30 are prepared by mixing 1.7 lt. diesel with 0.3 lt. rice bran oil and 1.4 lt. diesel with 0.60 lt. rice bran oil, respectively. It is noted that the viscosity of RBO is high. The properties of B15 and B30 fuels are calculated from properties of diesel and the rice bran oil. According properties of the fuels are represented in Table-3.

Table 3
Properties of Diesel, B15 and B30

	Calorific value (C in kJ/kg)	*Density (kg/m^3)*
Diesel	42000	830
Rice Bran Oil	37000	920
B15	41182	843.5
B30	40389	857

Results And Discussion

On the basis of various experimental data and the standard performance equations, both characteristics, i.e., performance and emission of the VCR Diesel engine using diesel, B15 and B30 as the fuels are calculated and presented in this section.

The brake power (BP) of the engine is calculated as

$$\mathrm{BP} = \frac{2 \times \pi \times \mathrm{N}\,(\mathrm{rpm}) \times \mathrm{Load}\,(\mathrm{kg}) \times \mathrm{g}(\mathrm{m/s^2}) \times \mathrm{S}\,(\mathrm{m})}{60 \times 1000} (\mathrm{kW})$$

The related brake thermal efficiency (BTE) of same engine is calculated as

$$\mathrm{BTE} = \frac{BP}{\dot{m}_{fuel} \times C_{fuel}} \times 100\,(\%)$$

Brake Power (Bp) Evaluation

The experiments are conducted for various load conditions likes 0 kg, 4.0kg, 8.0kg, 12.0kg, and 16.0kg under different compression ratios (CR) in order to evaluate the performance parameters. The considered compression ratios are 14, 16, and 18. For each compression ratio, three different experiments are conducted using the diesel, B15, and B30, separately. Following the calculation, Fig. 3(a) represents the brake power (BP) output for the compression ratio of 14 at various load conditions; whereas Fig. 3(b) and Fig. 3(c) represent the brake power (BP) output for the compression ratios of 16 and 18, respectively.

As observed from the Fig. 3, the brake power (BP) is increasing with increasing load condition at any of the compression ratios and any type of fuels, e.g., in case of pure diesel, the brake powers are 0 kW, 1.19 kW, 2.36 kW, 3.50kW, 4.6 kW for the compression ratio (CR) of 18 at 0kg, 4.0kg, 8.0kg, 12.0kg, and 16.0kg loads, respectively; and comparing the results for different compression ratios at any particular case of the fuels, it is found that the brake power increases with increasing compression ratio at par the standard. At 16 kg load using the pure diesel, the brake powers are found as 4.40kW, 4.50 kW and 4.59 kW for the compression ratios (CRs) of 14, 16, and 18, respectively.

Now, for any of the loads and compression ratios, the brake power output is almost same for diesel, B15 and B30. For an example, at 16 kg load and compression ratio of 16, the brake powers are 4.60743 kW, 4.61047 kW, 4.60743 kW for the diesel, B15 and B30, respectively, those are almost same.

Brake Thermal Efficiency (Bte)

Brake thermal efficiency (BTE) is another major parameter of the engine, presented here in order to understand the qualitative evolution of the chemical store energy during combustion of the fuels. Accordingly, experiments are conducted using three different fuels (diesel, B15 and B30) for different compression ratios (14, 16, and 18) at 0kg, 4.0kg, 8.0kg, 12.0kg, and 16 kg loads. Figure 4(a) represents the brake thermal efficiency for the compression ratio of 14 at various load conditions; Fig. 4(b) and Fig. 4(c) represent the brake thermal efficiency for the compression ratios of 16 and 18, respectively.

It is obvious from the Fig. 4 that the brake thermal efficiency (BTE) is increasing with increase in the load, which is applicable for any of the compression ratios and any type of fuels. It is also observed that the brake thermal efficiency (BTE) increases with increase in the compression ratio. As example, for B15 and 16 kg load, the brake thermal efficiency (BTE) in percentage (%) is 23.83, 23.89, and 23.95 at compression ratios (CRs) of 14, 16, and 18, respectively. Overall based on all the experiments, it is found that the BTE varies a little (an approx. average of 1.5%) on blending of rice bran oil with diesel.

Emission measurement

In order to maintain a green environment and standard of BS-VI for a diesel engine, reduction of emissions is essential at any cost in this decade. Blending of diesel with rice bran oil (RBO) is an option for reduction of the emissions. In this regard, all of the above experiments involve measurement of emissions, i.e., SOx, NOx, CO and hydrocarbon (HC) using a gas analyzer. The details of the emissions are presented here as:

SOx emission

Figure 5 represents emission of SOx at various load conditions for diesel, B15 and B30 under different compression ratios. Figure 5(a) presents SOx emission for compression ratio of 14, Fig. 5(b) and Fig. 5(c) present SOx emission for the compression ratios (CRs) of 16 and 18, respectively. As seen, the SOx emission has a decreasing nature with increase in compression ratio. For all of the experiments, it is found that SOx emission is less in case of B15 and B30 biofuels compare to the diesel. It is also observed that increasing blending of the rice bran oil with diesel does not reduce the SOx emission much, rather increase SOx emission on increase of blending of the rice bran oil (RBO). In Fig. 5(b), it is clear that SOx emission is more in case of B30 than B15. This limits the blending of rice bran oil to a maximum of 30% with diesel. Further, it is seen from Fig. 5 that SOx emission is low under the loads between 4kg to 12kg for all of the fuels. The average reductions of SOx emission on blending of RBO are 27.63%, 50.84%, and 67.97% for compression ratios (CRs) of 14, 16, and 18, respectively.

NO_X emission

NOx emission for all of the experiments is presented in Fig. 6 at various load conditions using diesel, B15 and B30 under the different compression ratios. Figure 6(a) presents NOx emission for compression ratio of 14, Fig. 6(b) and Fig. 6(c) present NOx emission for the compression ratios of 16 and 18, respectively. Figure 6 indicates that NOx emission is low at low and high loads, and a comparably increases at the moderate load. It is observed that the NOx emission is increasing with increase in compression ratio. However, the emission of NOx is reasonably low while the diesel as a primary fuel is blended with the rice bran oil (RBO). The average reductions of NOx emission on blending of RBO are 28.15%, 21.65%, and 12.71% for compression ratio of 14, 16, and 18, respectively.

CO emission

Emission of CO for all of the experiments is measured and presented in Fig. 7 at various load conditions using diesel, B15 and B30 as fuels under different compression ratios. Figure 7(a) presents the measured CO emission for compression ratio of 14, Fig. 7(b) and Fig. 7(c) present the CO emission measured for the compression ratios (CRs) of 16 and 18, respectively. As per the Fig. 7, CO emission is decreasing with increase in the load for all fuels and all compression ratios. As observed, the CO emission is little less in case of B15 and B30 compare to the diesel. The average reductions of CO emission on blending of RBO are 10.33%, 10.53%, and 19.87% for the compression ratios of 14, 16, and 18, respectively.

Hydrocarbon (Hc) Emission

Figure 8 represents the emission of hydrocarbon (HC) at various load conditions for diesel, B15 and B30 under different compression ratios. Figure 8(a) shows HC emission for compression ratio of 14, Fig. 8(b) and Fig. 8(c) show the HC emission for the compression ratios of 16 and 18, respectively. As seen from the Fig. 8, the HC emission is decreasing with increase in the compression ratio (CR). It is also seen from the Fig. 8 that the HC emission is high at low and high load conditions, and low HC emission at the moderate load condition, i.e., between 8 kg to 12 kg. As observed from the experiments, the HC emission is more in case of B15 and B30 biofuels compare to the diesel. The average increases of HC emission on blending of RBO are 12.66%, 2.5%, and 10.67% for compression ratio of 14, 16, and 18, respectively.

Conclusion

The present experimental study involves presentation of the characteristics for performance and emission of a VCR Diesel research engine powered by diesel and blended diesel with rice bran oils under different compression ratios (CR) and variable loading conditions. It is found that the brake power output is almost same for diesel as well as blended biofuels, i.e., B15 and B30. The variation of the brake thermal efficiency (BTE) is very little, an average of 1.5% for all of the fuels. Based on the emission analysis, SOx, NOx, CO emissions are decreasing on blending of diesel with the rice bran oil (RBO); and the blending of rice bran oil is suitable up to a limit of 30%. It is also observed that the engine emits less

pollutant on moderate operating load. However, HC emission increases with increasing blending percentage (%) of the rice bran oil with diesel, which is very less. In brief, on the basis of experimental results, this is concluded that blending of rice bran oil (RBO) is beneficial in accordance to reduce the emissions, and towards reaching to the standard of BS-VI.

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Figures

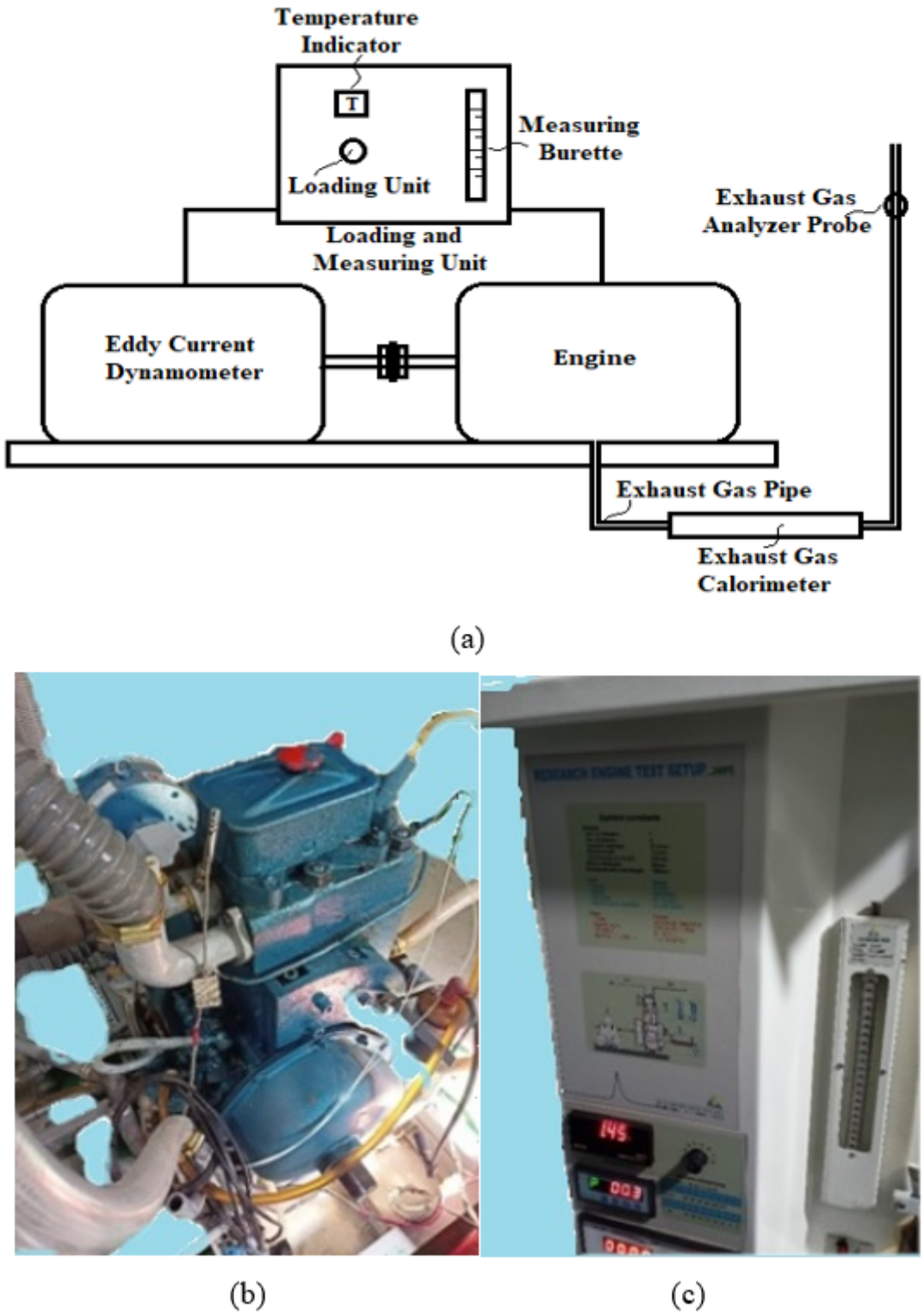

Figure 1

(a) Schematic of the experimental setup, (b) single cylinder variable compression ratio engine, and (c) loading and measuring unit

(a) (b)

Figure 2

(a) Preparation of blended biofuels, (b) two types of blended biofuels (B15 and B30)

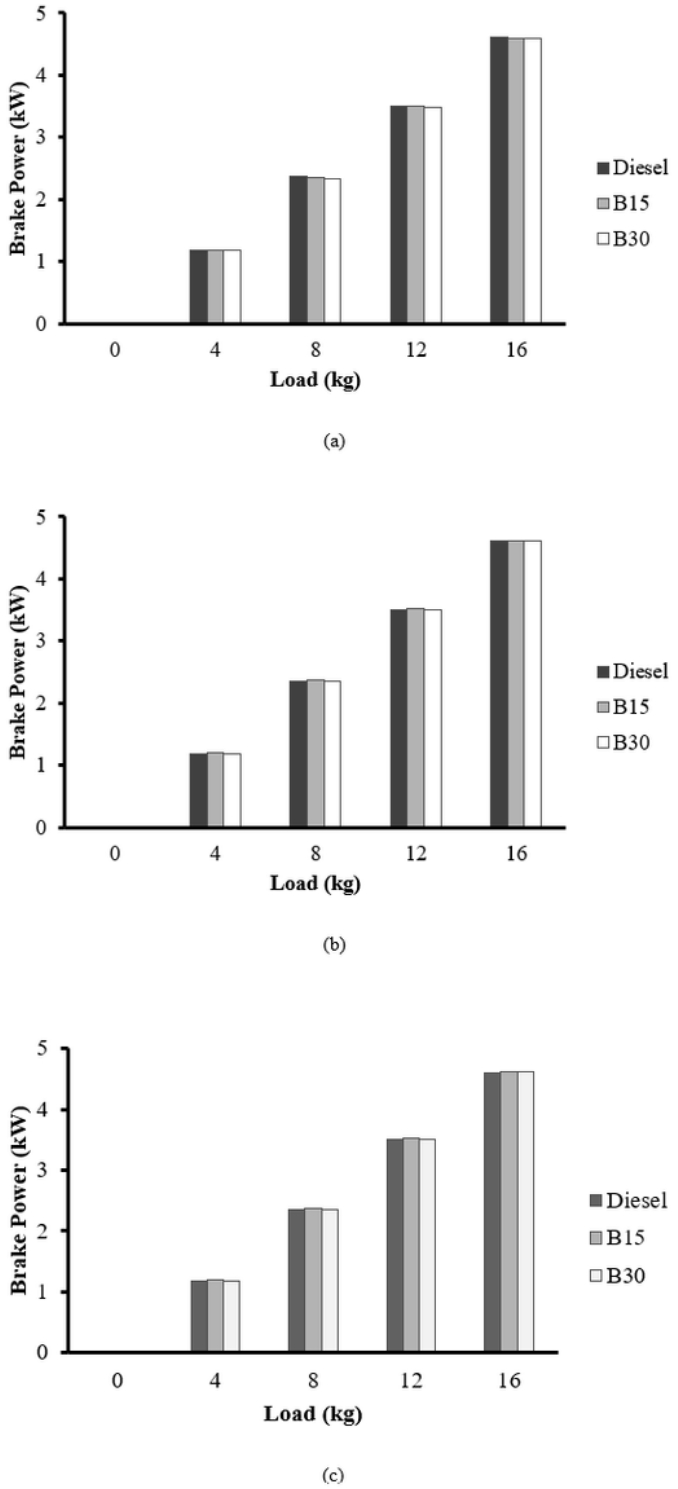

Figure 3

Comparison of the brake power (BP) output at different loads for (a) CR: 14, (b) CR: 16, and (c) CR: 18

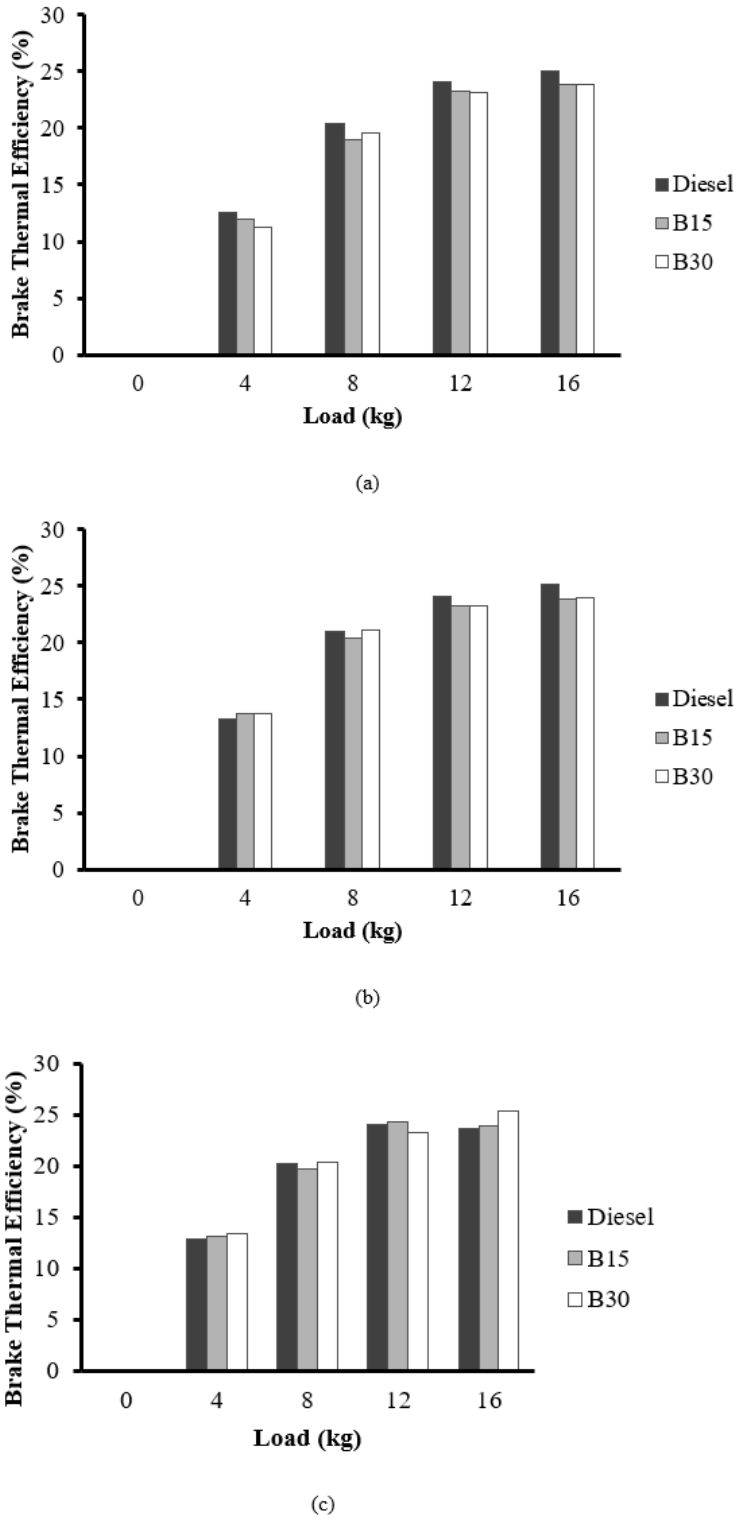

Figure 4

Comparison of the brake thermal efficiency (BTE in %) at different loads for (a) CR: 14, (b) CR: 16, and (c) CR: 18

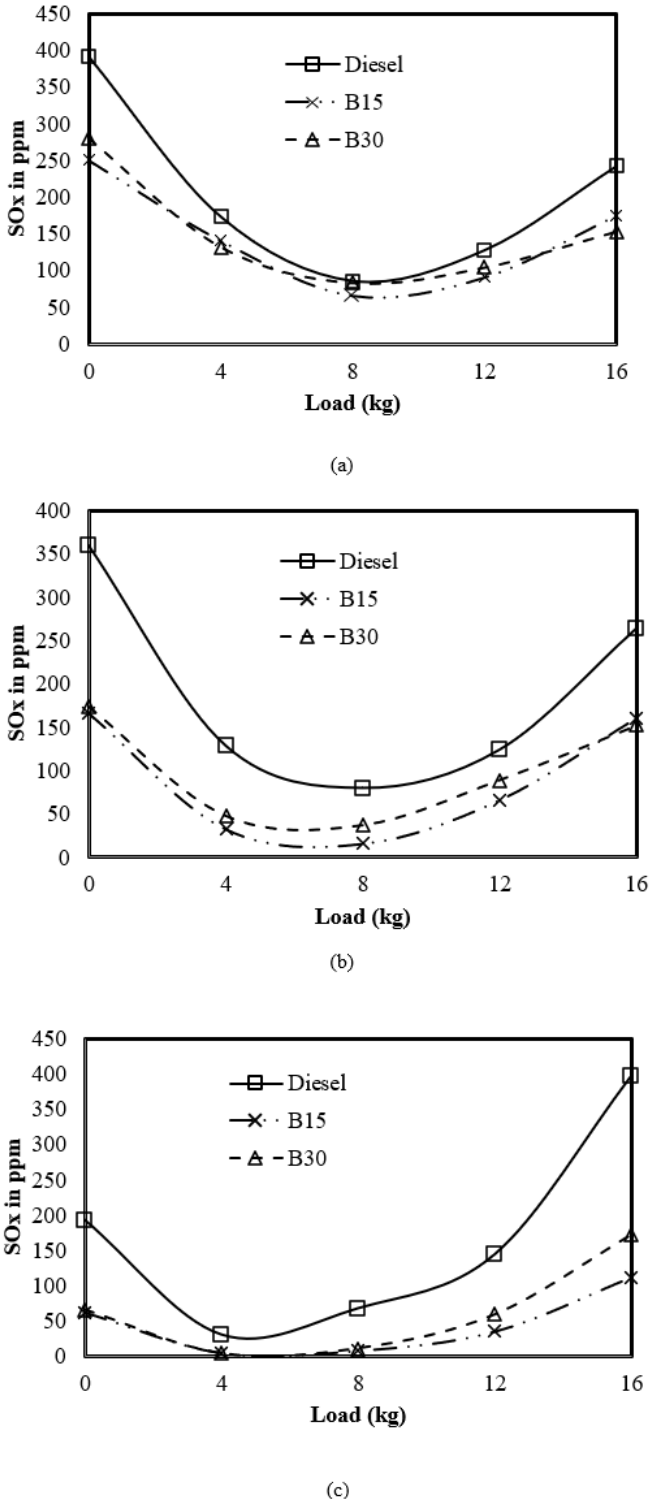

Figure 5

Comparison of SOx emission at different loads for (a) CR: 14, (b) CR: 16, and (c) CR: 18

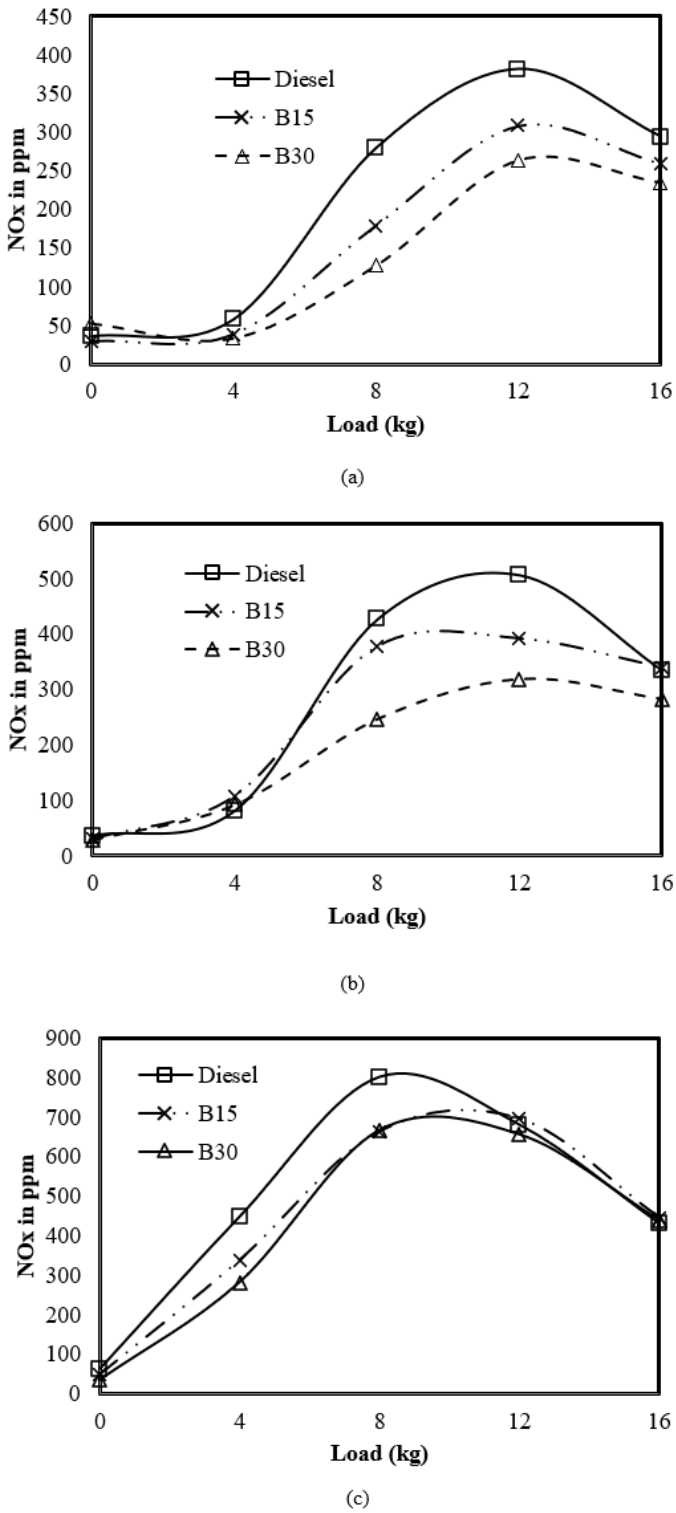

Figure 6

Comparison of NOx emission at different loads for (a) CR: 14, (b) CR: 16, and (c) CR: 18

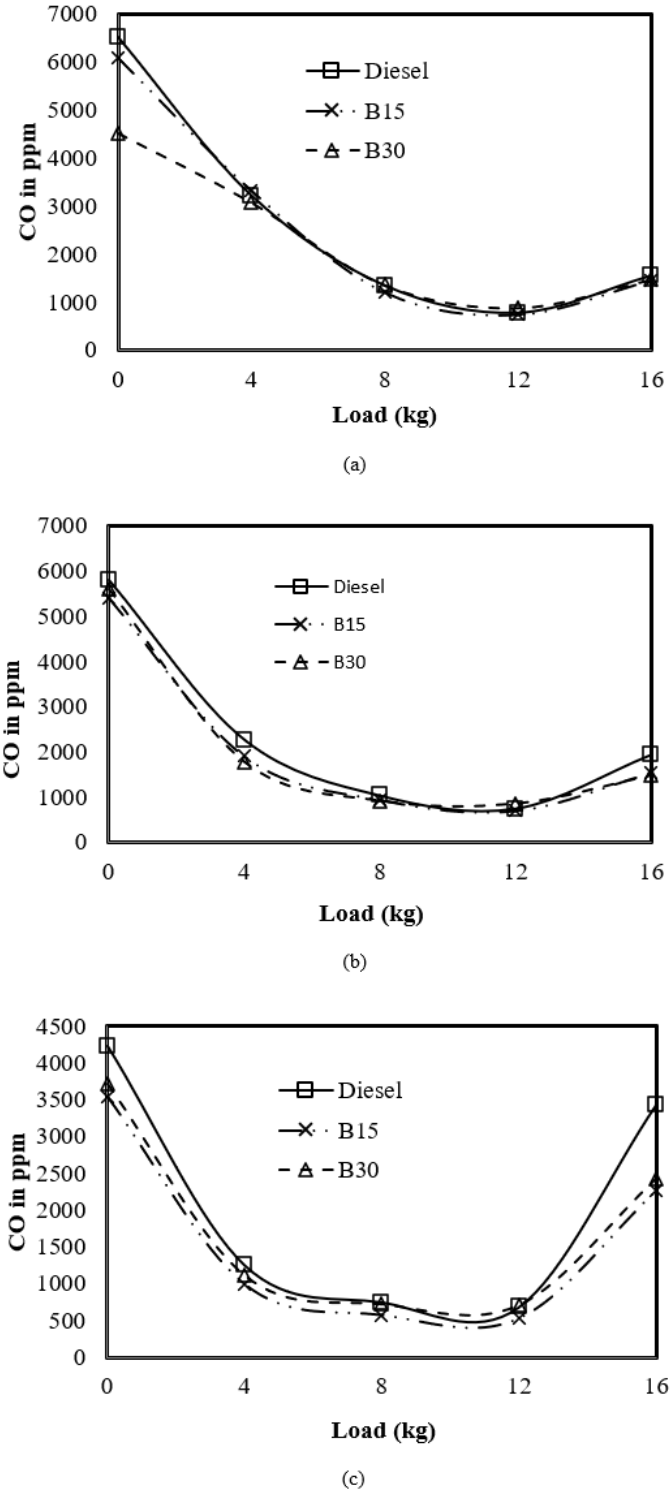

Figure 7

Comparison of CO emission at different loads for (a) CR: 14, (b) CR: 16, and (c) CR: 18

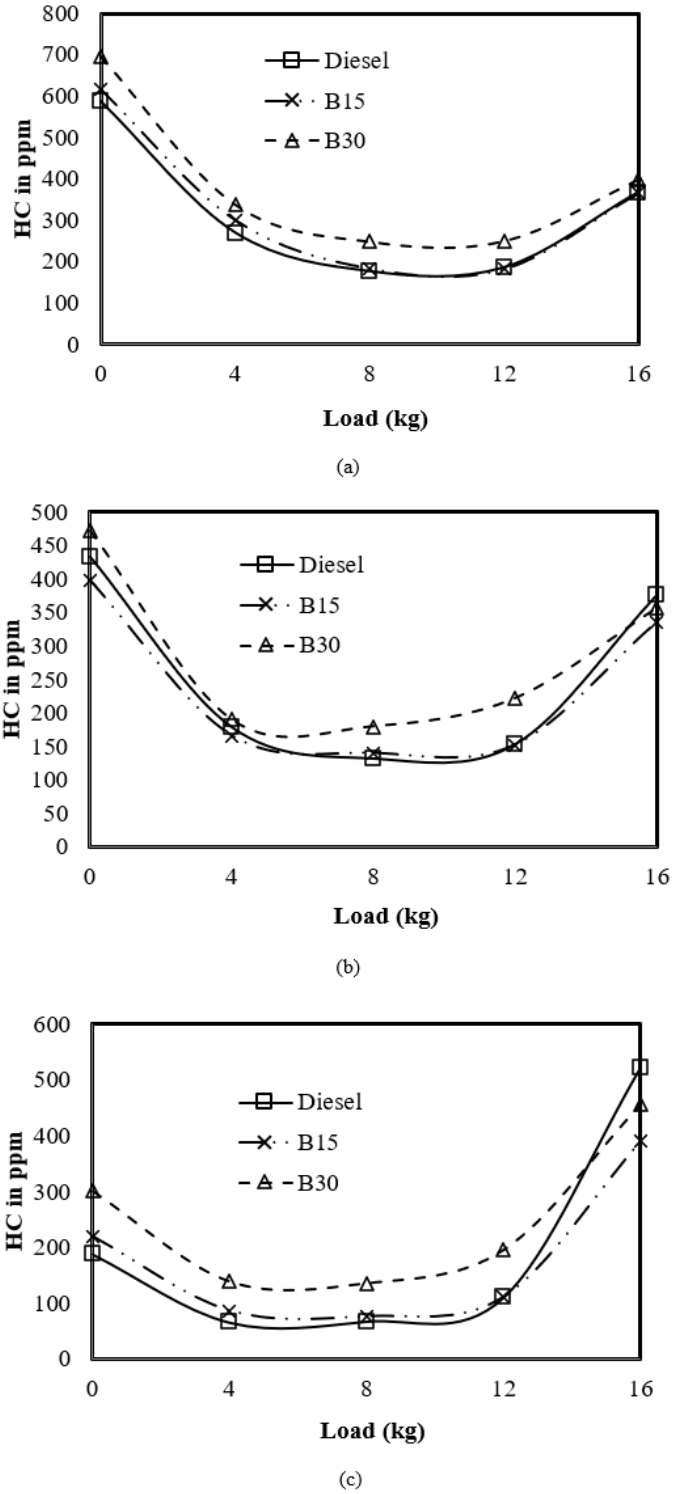

Figure 8

Comparison of HC emission at different loads for (a) CR: 14, (b) CR: 16, and (c) CR: 18