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Full Length Research Paper

Performance and emission characteristics of karanja methyl esters: Diesel blends in a direct injection compression-ignition (CI) engine

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Biodiesel is a fatty acid alkyl ester which is renewable, biodegradable and non toxic fuel which can be derived from any vegetable oil by transesterification process. One of the popularly used non edible biodiesel in India is karanja oil methyl ester (KOME). In the present investigation, karanja oil based methyl ester (biodiesel) blended with diesel were tested for their use as a substitute fuel for diesel engine. Experiments were conducted to study the performance and emission characteristics of a direct injection diesel engine using blends of karanja methyl esters with diesel on a 10, 20, 30, 40 and 50% volume basis, respectively. The acquired data were analysed for various parameters, such as brake thermal efficiency, carbon monoxide (CO), hydrocarbon (HC), Smoke and nitrogen oxide (NOx) emissions. Engine performance showed that brake thermal efficiency for 50% biodiesel blend is 21.69% poorer than diesel. Emission characteristics of CO, HC and smoke were found lower with biodiesel blends. However, oxides of nitrogen were 26% higher for 50% biodiesel blend as compared to diesel.

Key words: Biodiesel, transesterification, karanja oil, methyl ester, emission.

INTRODUCTION

Invention of the internal combustion engine has tremendously increased our day-to-day energy demand. This has resulted in the wide spread exploitation of the petroleum reserves, which are getting depleted at a rapid rate. Moreover, the combustion of these fuels has polluted the environment to alarming levels. In search of the alternate fuels, people have used various fuels like propane (LPG), methane (CNG), hydrogen (H_2), alcohols, vegetable oils, etc., (Nanthagopal and Rayapati, 2009). It has been found that vegetable oil has special promise in this regard, since they can be produced from plants grounded in rural areas (Babu et al., 2003). In this contest, many varieties of vegetable oils have been evaluated in many parts of world, but only very few oil such as jatropha oil and Karanja oil can be considered to be economically affordable to nations like India in particular. The use of straight vegetable oils is restricted by some unfavorable characteristics, like carbon deposit buildup, poor durability, poor fuel atomization and also poor thermal efficiency. The problems associated with straight vegetable oils can be solved by any one of the four processes via pyrolysis, micro emulsification, dilution or transesterification of oil to produce biodiesel (Sahoo and Das, 2009; Ramadhas et al., 2004). It has been reported that transesterification process is the best effective method of biodiesel production and an important role in the viscosity reduction of vegetable oil. Biodiesel is referred to as the mono-alkyl-esters of long chain fatty acids derived from renewable lipid sources. It is the name for a variety of eater based oxygenated fuel from renewable biological sources. In the present investigation, the transesterified non edible oils of karanja have been considered as a potential alternative fuels for diesel engines.

A large number of experiments were carried out with vegetable oils as a replacement of compression-ignition (CI) engine fuel by researchers from various part of the world. The use of karanja methyl ester in diesel engine has been reported by (Rehmann and Phadatare, 2004). It

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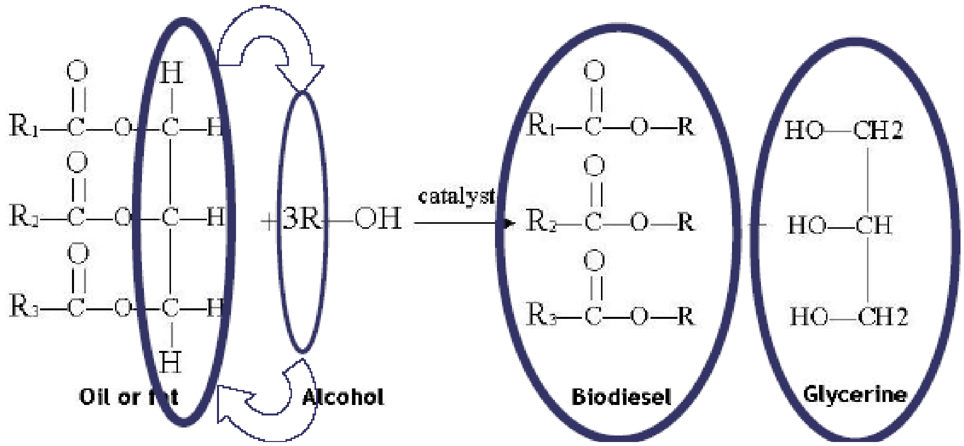

Figure 1. Transesterification process of biodiesel.

Table 1. Properties of karanja (KB) methyl ester and diesel.

Property	Diesel	Karanja oil methyl ester
Density (kg/m^3)	850	883
Kinematic viscosity at 40°C (Cst)	2.87	4.37
Flash point (°C)	76	163
Calorific value (kJ/kg)	44000	42133

was reported that blends of karanja methyl ester with diesel reduces emissions, such as carbon monoxide (CO), smoke density and nitrogen oxide (NOx) on an average of 80, 50 and 26%, respectively. It was found out that brake power output increases on an average 6% up to B40 biodiesel blend and decreases further with increase in biodiesel blends.

This study targets at making a comparison of the methyl esters of karanja oil in a diesel engine vis-à-vis diesel fuel. The performances and emissions of the engine characteristics were evaluated using different proportions and were compared using diesel.

MATERIALS AND METHODS

Transesterification

Transesterification is also known as alcoholysis. It is a chemical process in which triglycerides in vegetable oils are converted to mono alkyl esters of the same fatty acid, which are called biodiesel. It is the reaction of fat or oil with an alcohol form esters and glycerin. A catalyst is used to improve the reaction rate of the transesterification process (Figure 1). Among the alcohols, methanol and ethanol are used commercially because of their low cost and their physical and chemical advantages. To complete a transesterification process, 3:1 molar ratio of alcohol is needed. Enzymes, alkalis or acids can catalyze the reaction, that is, lipases, KOH, NaOH and sulphuric acid, respectively. Among these, alkali transesterification is faster, hence, it is used commercially (Forson et al., 2004; Reed et al., 1992; Murugesan et al., 2009).

Transesterified karanja was blended with diesel oil in varying proportions with the intention of reducing its viscosity close to that of the diesel fuel. The blends prepared were stable under normal conditions. The fuel properties of karanja methyl esters and diesel are summarized in a tabular form as shown in Table 1.

Experimental set up and test procedure

A 4.4 kW, 1500 rpm, single cylinder, four-stroke, naturally aspirated, air-cooled, direct injection vertical diesel engine coupled with an eddy current dynamometer is used in this analysis (Figure 2). Specifications of the engine are presented in Table 2. Engine torque was measured with a strain gauge type load cell mounted between the stator and the base frame of dynamometer. The major pollutants in the exhaust of a diesel engine are smoke. AVL smoke meter was used to measure the smoke density of the exhaust from diesel engine. QRO-TECH five gas analyzer was used for the measurement of CO, hydrocarbon (HC) and NOx emissions. The engine was operated on diesel first and then on methyl esters of karanja and its blends. The different fuel blends and mineral diesel were subjected to performance and emission tests on the engine. The performance data were then analyzed from the graphs regarding thermal efficiency, brake-specific fuel consumption and smoke density of all fuels. The brake-specific fuel consumption is not a very reliable parameter to compare different fuels, as the calorific values and the densities are different.

RESULTS AND DISCUSSION

A series of exhaustive engine tests were carried out using diesel and different biodiesel blends ranging from B10 to B50. The engine performance and emissions data

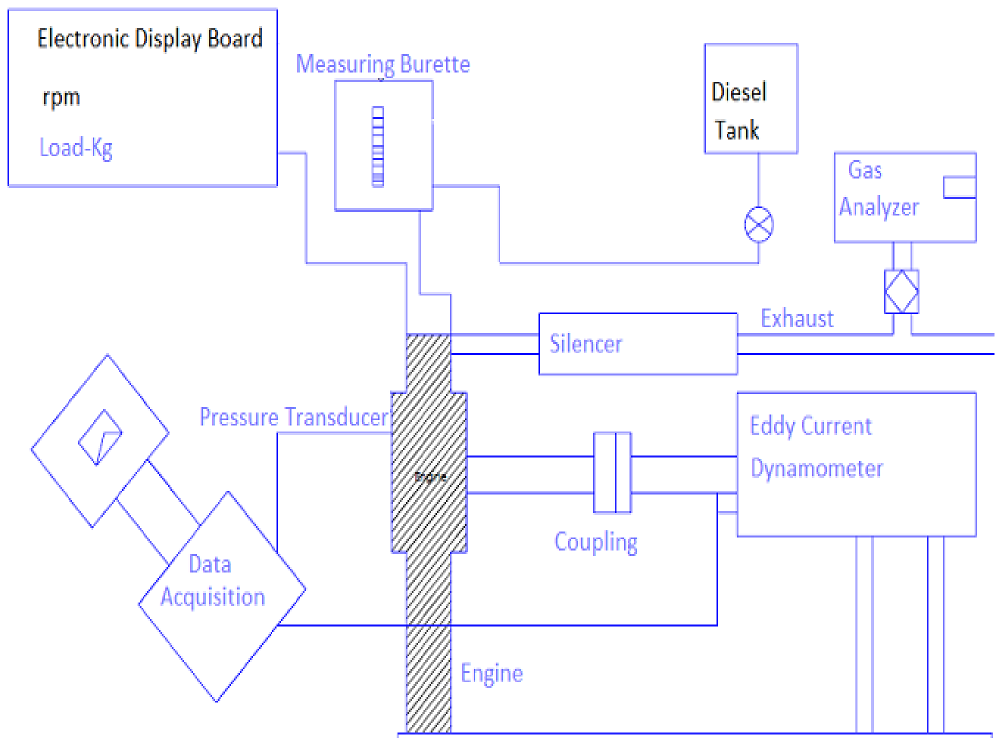

Figure 2. Schematic diagram of the experimental set up.

Table 2. Engine specifications.

Model	**Kirloskar TAF1**
Type	Single cylinder, four stroke. Direct injection, bowl-in-piston combustion chamber
Bore and stroke	87.5 × 110 mm
Compression ratio	17.5 :1
Rated power	4.4 kW at 1500 rpm
Injector opening pressure	205 bar
Injection timing	23°bTDC
Dynamometer	Eddy current

obtained for biodiesel blends were compared with baseline data for diesel. Characteristics curves for brake thermal efficiency, CO, HC, smoke and NOx emissions were drawn for different biodiesel blends and diesel. These curves are shown in Figures 3 to 7.

Brake thermal efficiency

Brake thermal efficiency (BTE) is one the main performance parameters which indicates the percentage of energy present in the fuel that is converted into useful work. The comparison of BTE of the various blends of karanja with diesel (KB10, KB20, KB30, KB40 and KB50) and clean diesel is as shown in Figure 3. The BTE of karanja blends were lower than diesel for the entire load. The decreasing trend in efficiency with increase in concentration of biodiesel in diesel may be because of lower calorific value of methyl esters than that of diesel. It may also be caused by its poor atomization due to its high viscosity.

Smoke opacity

The variation of smoke emission with brake power for biodiesel blends and diesel is as shown in Figure 4. The smoke that is formed due to incomplete combustion is much lower for biodiesel and its diesel blends as compared to neat diesel. This is because of complete combustion of methyl esters as compared to diesel fuel. However, with increase in percentage of biodiesel blends,

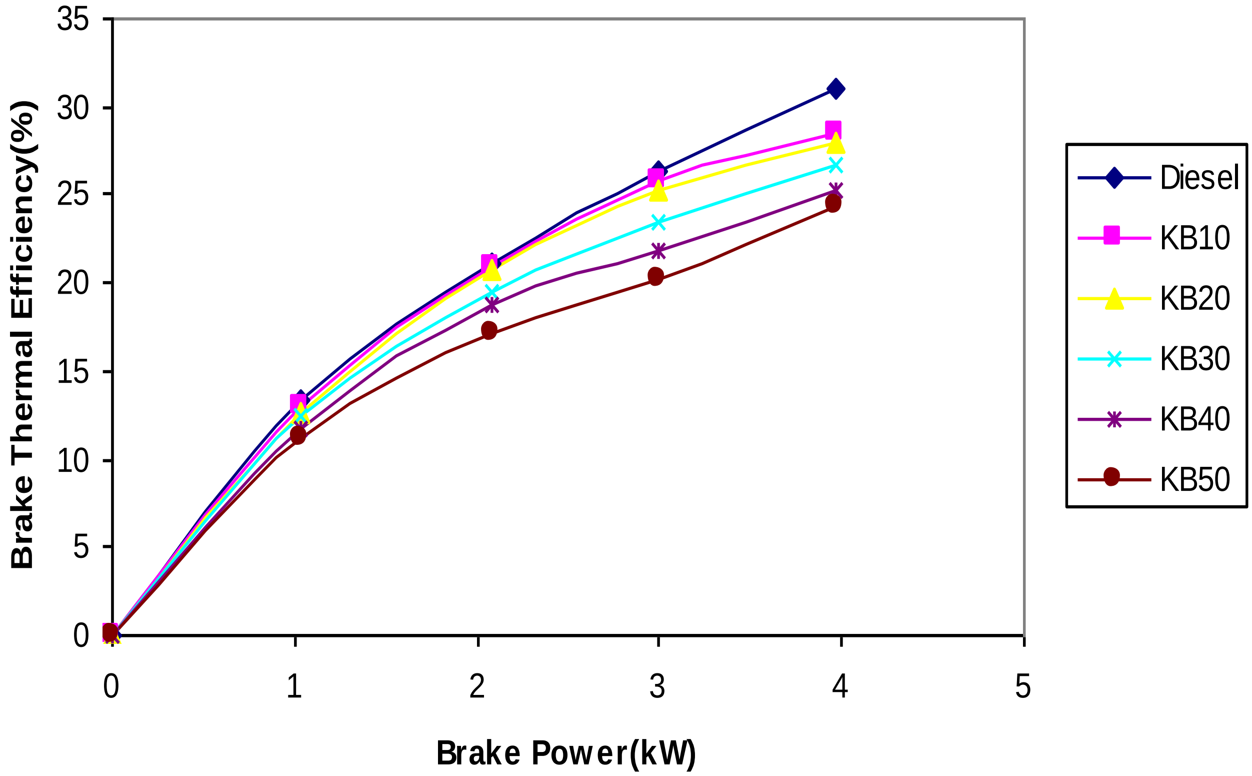

Figure 3. Variation of BTE with brake power.

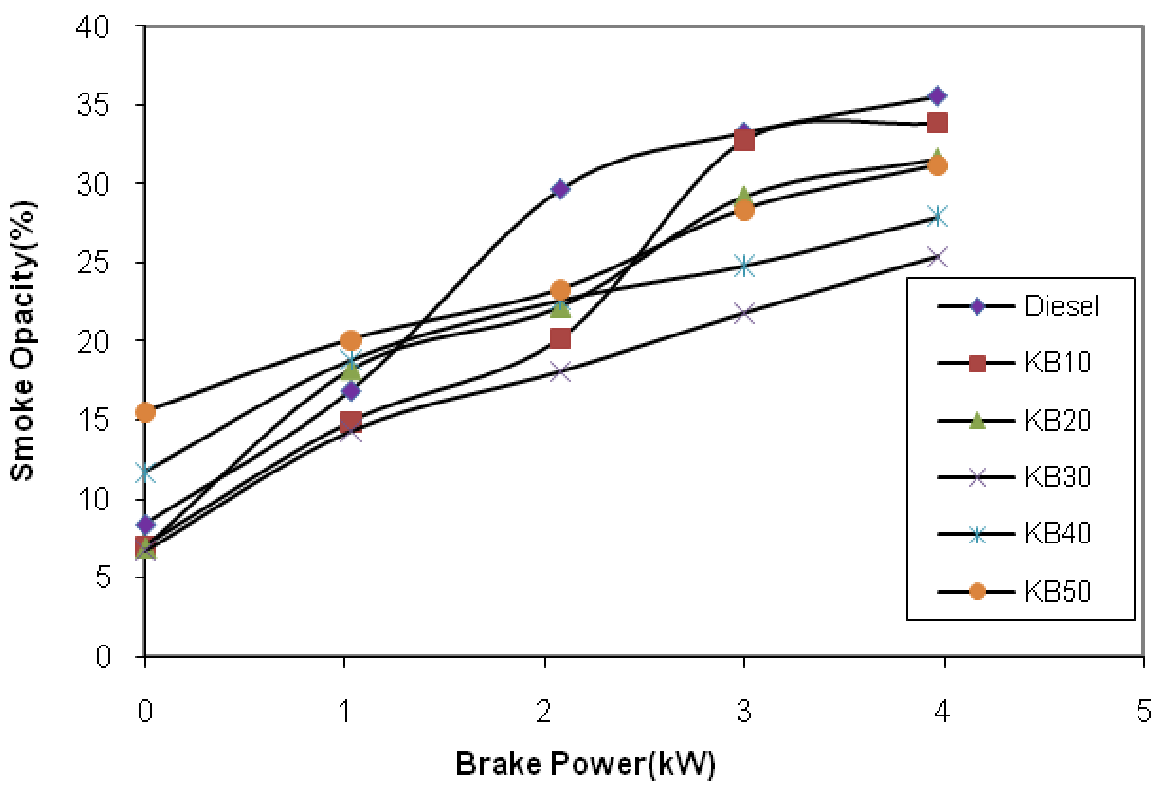

Figure 4. Variation of smoke opacity of different fuels.

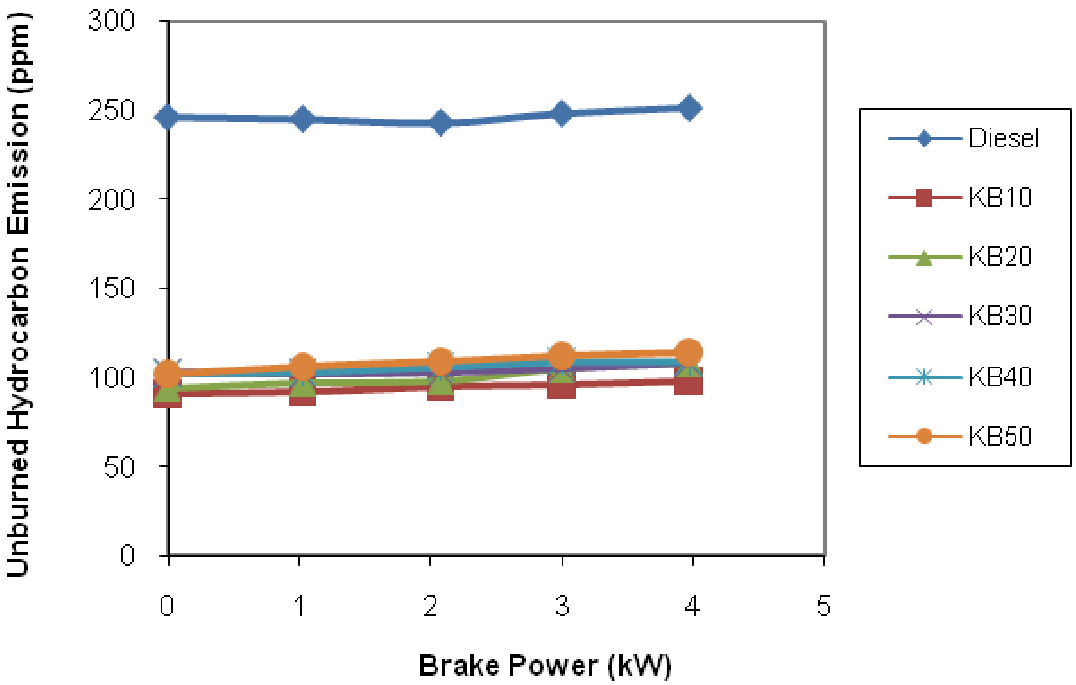

Figure 5. Variation of HC emissions of different fuels.

smoke density decreases.

Unburned HC emission

Unburned HC is also an important parameter for determining emission behaviour of the engines. Figure 5 shows the variation of HC emission with brake power for different fuels. It is observed that HC emission of the various blends was lower at partial load, but increased at higher engine load. This is due to the availability of less oxygen for the reaction when more fuel is injected into the engine cylinder at higher engine load. It is also observed from the Figure 5 that biodiesel blends give relatively lower HC as compared to the diesel. This is because of better combustion of the biodiesel inside the combustion chamber due to the availability of excess content of oxygen in the biodiesel blends as compared to clean diesel.

Emission of NOx

NOx emissions are extremely undesirable. NOx is one of the main emissions in diesel engine. NOx is more likely to cause respiratory problems such as asthma, coughing, etc. Three conditions which favor NOx formation are higher combustion temperature, more oxygen content and faster reaction rate. The above conditions are attained in biodiesel combustion very rapidly as compared to neat diesel. Hence, NOx formations for biodiesel blends are always greater than neat diesel. It can be observed from Figure 6 that at higher power output conditions, due to higher peak temperatures, the NOx values are likely higher for both biodiesel and clean diesel fuel.

Carbon monoxide (CO) emission

Carbon monoxide emissions occur due to the incomplete combustion of fuel. The emissions of carbon monoxide are toxic. The comparative analysis is as shown in Figure 7. Biodiesel blends give less carbon monoxide as compared to diesel due to complete combustion. When the percentage of blend of biodiesel increases, carbon monoxide decreases. This is due to more amount of oxygen content of biodiesels that result in complete combustion of the fuel and supplies the necessary oxygen to convert CO to CO_2.

Conclusion

Conclusively, the performance and emissions characteristics blends of the biodiesel from karanja are analysed and compared with that of the diesel. It was found out that biodiesel blends have lower brake thermal efficiency than diesel. Emissions of NOx are found to be high for biodiesel blends. CO, HC and smoke emissions are lower for biodiesel blends as compared to diesel.

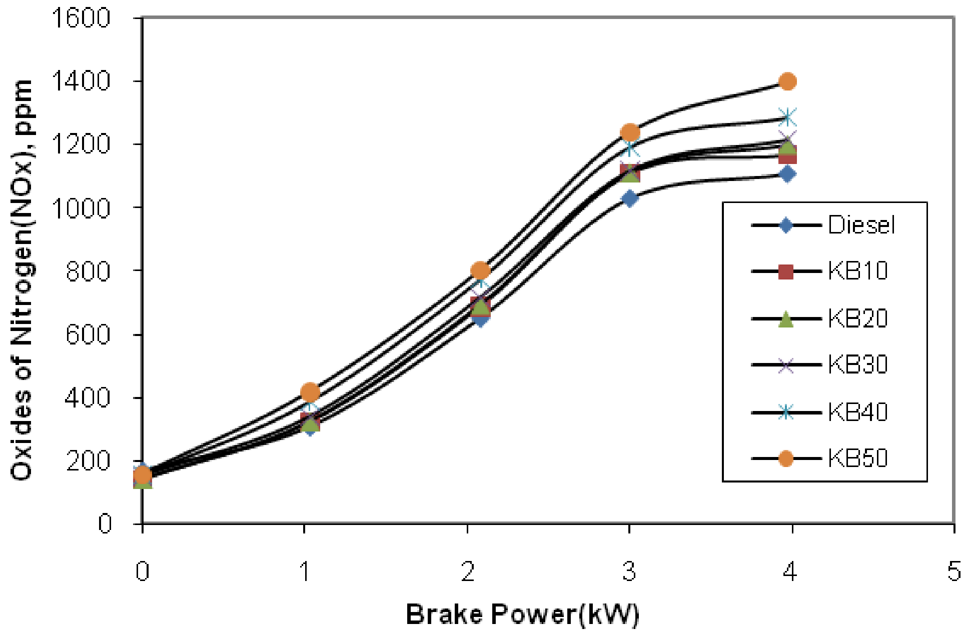

Figure 6. Variation of NO_x emissions of different fuels.

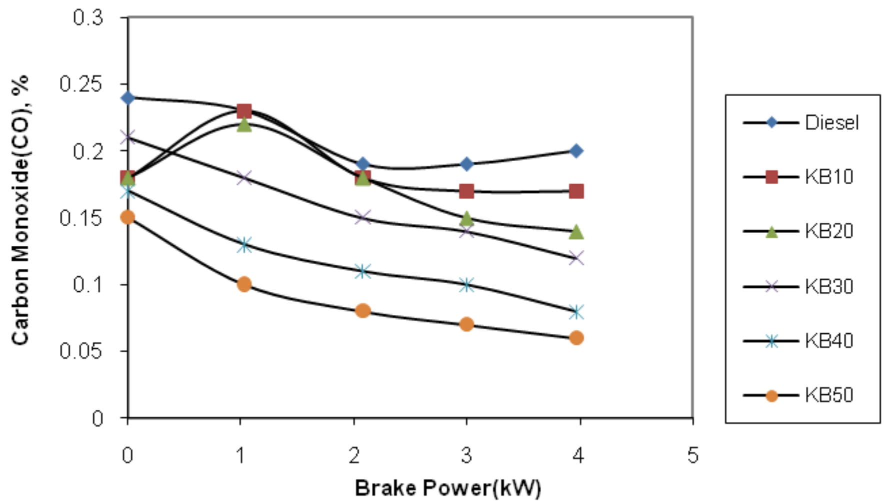

Figure 7. Variation of CO emissions of different fuels.

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