ISSN: 2277-9655
Impact Factor: 4.116

IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

AN EXPERIMENTAL INVESTIGATION ON PERFORMANCE, COMBUSTION AND EMISSION PARAMETERS BIODIESEL-WATER EMULSION ON A DI DIESEL ENGINE

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ABSTRACT

With the rapid depletion of fossil fuels and their increasing demand has led to choice biodiesel as an alternative fuel for diesel engine without any engine modification. Investigations have been carried out to study the reduction of oxides of nitrogen emission and smoke emission on a single cylinder, direct injection diesel engine with eucalyptus oil-water emulsion as fuel. Primarily the properties of chosen oil were compared with other biodiesel fuels which had already been tested and experiments were performed by varying the quantity of water from 10% to 30% (in volume) in eucalyptus oil water emulsion blend with diesel. From the results it was inferred that 30% water emulsion with biodiesel could significantly reduce NOx by 30% and smoke emission by 32% without adverse effect on brake thermal efficiency, when compared with diesel fuel at full load condition of the engine without emulsion and comparatively at very low cost to other emission control methods.

KEYWORDS: Diesel engine, Eucalyptus oil-water emulsion, Brake thermal efficiency, Oxides of nitrogen emission, Smoke emission.

INTRODUCTION

In view of growing demand for diesel for transportation and power generation, the search for an alternative fuel has become inexorable and this has led to the usage of vegetable oil as substitute for diesel in diesel engine. Since vegetable oil cannot be used directly in the diesel engine due to their high viscosity, they are converted into biodiesel with the transesterification process [1] and this biodiesel is used as an alternative fuel for diesel engine without engine modification [2]. The biodiesel used in the diesel engine has several positive features such as it is miscible with petro diesel, better lubricity, higher flash point, highly biodegradable and lower exhaust emission. It also has negative aspects as low temperature operability, low energy content, poor oxidative stability and higher oxides of nitrogen (NO_x) emission and smoke emission [3-4]. The oxidation stability can be improved by adding cold flow properties [5]. The exhaust gas emission of biodiesel can be improved by emulsification of biodiesel with water [6-7] and the other strategies involve selective catalytic reduction (SCR) and exhaust gas recirculation (EGR).The experiment on diesel engine with natural gas EGR technique [8-9]. The emulsification of biodiesel with 10%, 20%, and 30% of water blend also gives reduction in NO_x and smoke emission. [10]. The DI diesel engine fuelled with cotton seed oil methyl ester and showed that the 30% water emulsion of this biodiesel effectuated substantial reduction of NO_x by 30% and smoke emission by 32% compared with diesel at full load condition without emulsion. The water emulsified biodiesel also adds certain explicit factors in controlling the NO_x and smoke emission [11-12]. The brake thermal efficiency of the diesel engine improved comparatively reduction in NO_x emission when biodiesel with water emulsion in the ratio 10% and 20% was used in direct injection diesel engine [13]. The emulsified biodiesel improved the trade off relation between NO_x and smoke emission [14]. The specific fuel consumption and reduction in NO_x and smoke emission when 13% volume of water emulsified was used in diesel engine [15]. From the previous studies, it is observed that most of the analyses were mainly related to performance, combustion and emission characteristics of diesel engine using neat biodiesel. Hence in this paper a detailed analysis of performance and emission of diesel engine with eucalyptus oil used as biodiesel after emulsification with water in the ratio of 10%, 20% and 30% of its volume at full load condition of the engine was carried out and compared with the characteristics of engine with that of diesel and biodiesel.

PREPARATION OF EUCALYPTUS-WATER EMULSION

The experiment was performed with transesterification of eucalyptus oil. At the end of transesterification process the eucalyptus oil was converted into its methyl ester. The transesterification reaction involves mixing of 8 gram of KOH catalyst per litre of eucalyptus oil with 200 ml of methyl alcohol to obtain methoxide. The eucalyptus oil and methoxide mixture were heated at 65˚C with constant stirring for 1 hour. The resultant was cooled and allowed to settle for 8 hours in a separating funnel and then the glycerol layer was drained off from the bottom of the flask. The left over in the flask was esterified vegetable oil i.e., the biodiesel. The properties of the biodiesel were found to be closer to those of diesel fuel. Then the resultant biodiesel was emulsified with water in the ratio of 10%, 20%, and 30% of its volume. The properties of diesel, eucalyptus oil and eucalyptus oil water emulsion are listed in Table1.

Table 1: Properties of diesel, biodiesel and emulsified biodiesel

PROPERTIES	BIODIESEL	EMULSIFIED BIODIESEL	DIESEL
Viscosity(mm^2/g)	9.1	5.35	3.9
Density(kg/m^3)	906	890	860
Calorific value(MJ/kg)	38.6	39.2	43.5
Flash point(°C)	209	205	72
Fire point(°C)	240	210	80
Cetane number	50	52	48

EXPERIMENTAL SET-UP

The experimental set-up consisted of Kirloskar diesel engine of AV1model, four stroke, direct injection and water cooled diesel engine. The schematic representation of the experimental set-up is shown in Figure 1. The engine were coupled with an eddy current dynamometer, the calibrated burette controled the fuel flow rates, the piezoelectric sensor measured the cylinder pressure and the pressure signals were amplified with Kistler charge amplifier model 5011B. The heat release rate was analyzed with combustion analyser and a crank angle encoder was used for crank signal acquisition. The AVL-44 five gas analyzer and smoke meter were used to measure the exhaust gas emissions such as CO, NO, HC and smoke emission respectively. Inlet and outlet water and exhaust gas temperature were like 25%, 50%, 75%and 100% load with emulsified biodiesel and compared to other biodiesel fuel. The engine specifications are tabulated in Table 2.

Table 2: Specifications of Engine

ENGINE	KIRLOSKAR AVL
Power(kW)	3.67
Bore(mm)	80
Stroke(mm)	110
Compression ratio	16.5:1
Speed(rpm)	1500
Number of cylinder	1

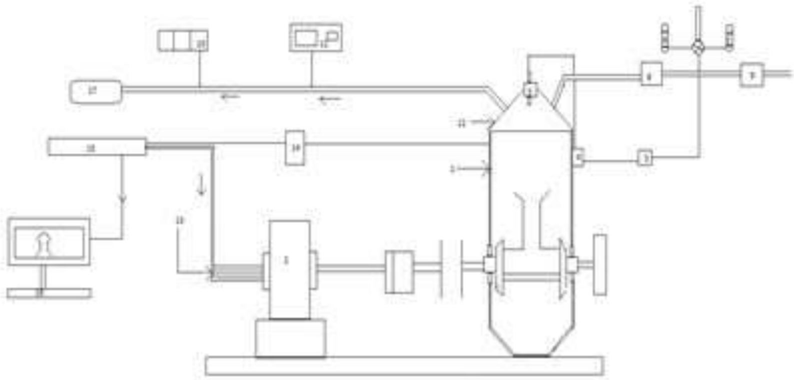

Figure 1:Schematic diagram of experimental setup

1. Kirloskar AV1 engine *2. Eddy current dynamometer* *3. Injector*
4. Fuel pump *5. Fuel filter* *6. Diesel tank*
7. Fuel tank *8. Air stabilizing tank* *9. Air filter*
10. AVL Smoke meter *11. AV1 44 five-gas analyser* *12. Pressure transducer*
13. TDC Encoder *14 .Charge amplifier* *15.Indimeter*
16. Monitor *17. Exhaust silencer*

RESULTS AND DISCUSSION

Performance characteristics

Brake Thermal Efficiency (BTE)

The Figure 2 shows increase in the brake thermal efficiency with the increase in load for all test fuels. The brake thermal efficiency of biodiesel is lower than that of diesel. The thermal efficiency is indication of the efficiency with which chemical energy input in the form of fuel is converted into the work (16). It is due to its calorific value and volatility but the water emulsified eucalyptus oil biodiesel fuel gives higher brake thermal efficiency (BTE) at full loads when compared with biodiesel. The flashpoint, poor volatility may have an influence on the combustion process of biodiesel (17). The reason is due to the micro explosion phenomenon and volatility difference between water and the fuel and this results in improved combustion efficiency. The brake thermal efficiency of 20% emulsified biodiesel is 7% higher than that of biodiesel fuel at full load.

Brake Specific fuel consumption(BSFC)

The Figure 3 shows brake specific fuel consumption (BSFC) of all test fuels decreasing with increase in load. On comparing the results, we found the 10% water emulsion of eucalyptus oil biodiesel having higher brake specific fuel consumption than that of diesel and biodiesel. The brake specific fuel consumption of 10% water emulsion of biodiesel is 0.279 kg/kWh at full load, whereas for diesel and biodiesel fuel it is 0.240 kg/kWh and 0.259 kg/kWh respectively. This is due to the lower energy content of the biodiesel.

Exhaust Gas Temperature

The Figure 4 shows exhaust gas temperature increasing with increases in load and it is higher for biodiesel when compared with diesel, but for emulsified fuels the exhaust gas temperatures are found lower than those of biodiesel(18). This is because the water in the emulsion gets vaporised during the combustion process and absorbs heat energy which decreases the adiabatic flame temperature. The exhaust gas temperature of diesel and biodiesel are 302°C and 335°C. The 30% water emulsion of eucalyptus oil biodiesel shows the maximum reduction of exhaust gas temperature by 26% (265°C) at full load.

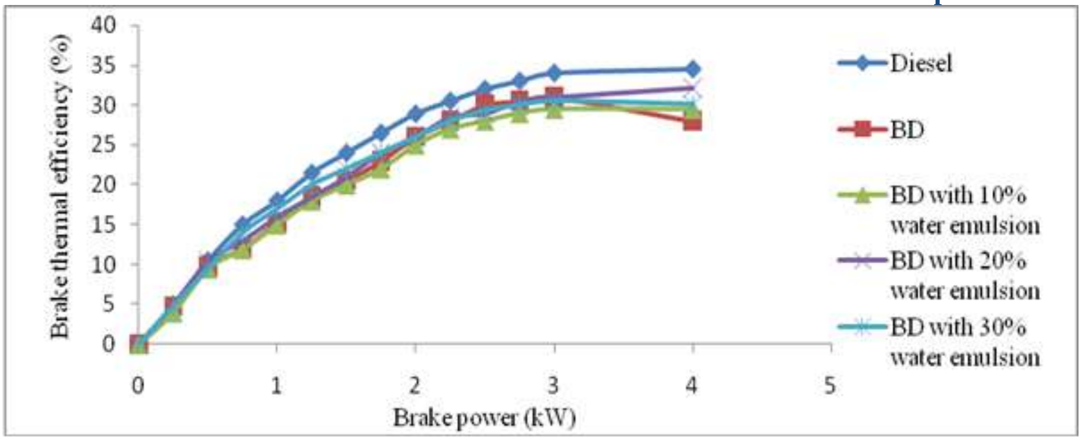

Figure 2:Variation of brake thermal efficiency with brake power

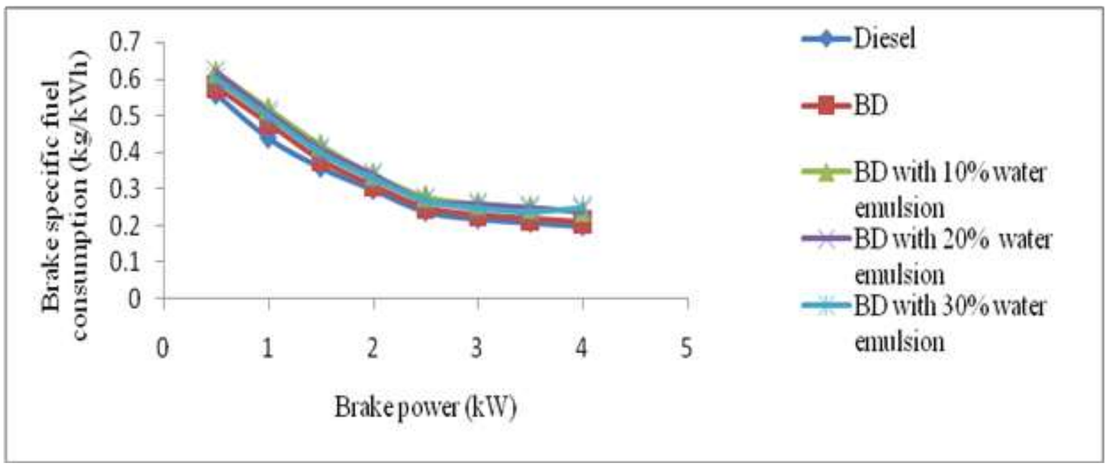

Figure 3:Variation of brake specific consumption with brake power

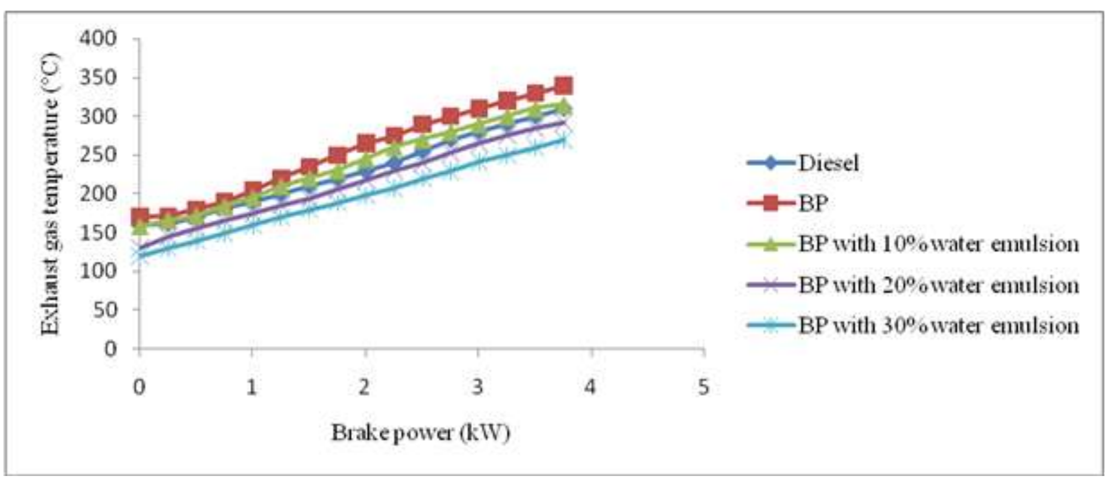

Figure 4:Variation of exhaust gas temperature with brake power

ISSN: 2277-9655
Impact Factor: 4.116

Combustion characteristic

The emulsified eucalyptus oil biodiesel has higher peak pressure value at its full load than the values of diesel and biodiesel at its full load. This is because the vaporization of water in the combustion chamber creates an increased ignition delay period which in turn increases the premixed combustion period for emulsified fuel and hence leads to high peak pressure. The peak pressure value of 30% emulsified biodiesel has higher value than that of diesel and biodiesel. The peak pressure value of 30% emulsified biodiesel is 73.5 bar whereas for diesel and biodiesel the peak pressure values are 72 bar and 70 bar respectively at the full load. The vaporization of water in the combustion chamber creates a higher ignition delay period which directly affects the heat release rate. As the delay period increases, the premixed combustion period of the emulsified fuel increases and leads to higher heat release rate of the emulsified fuel when compared with diesel and biodiesel. It is found from the results that the heat release rates for 10%, 20% ,and 30% emulsified eucalyptus oil biodiesel are 113 J/deg.CA, 115 J/deg.CA and 117 J/deg.CA respectively at its full load and the heat release rate of diesel and biodiesel are 112 J/deg.CA and 107 J/deg.CA respectively at the full load. The combustion characteristics curves of water emulsified eucalyptus oil are shown in figures 5 and 6 respectively.

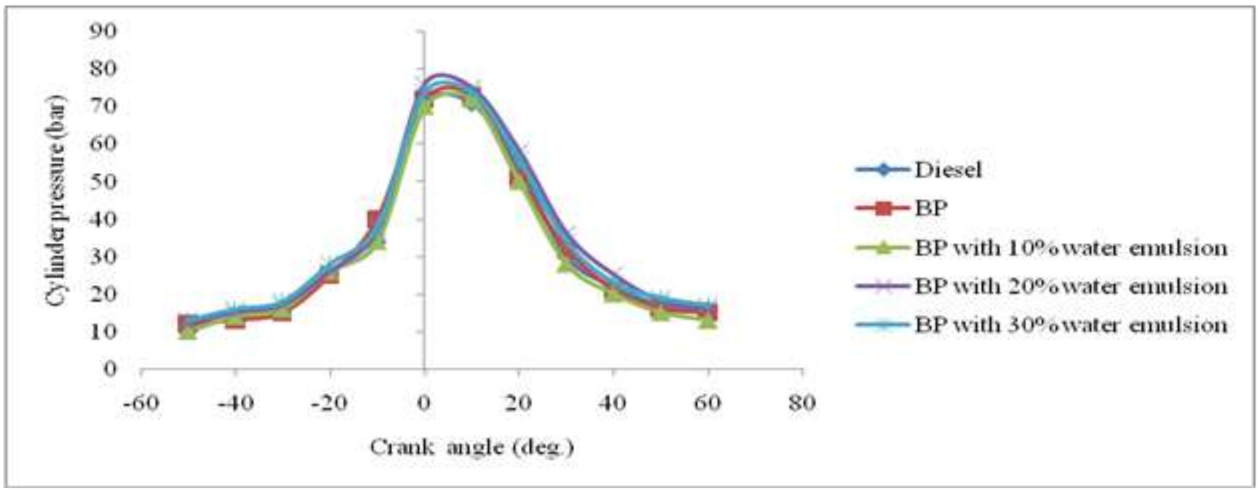

Figure 5:Variation of cylinder pressure with crank angle

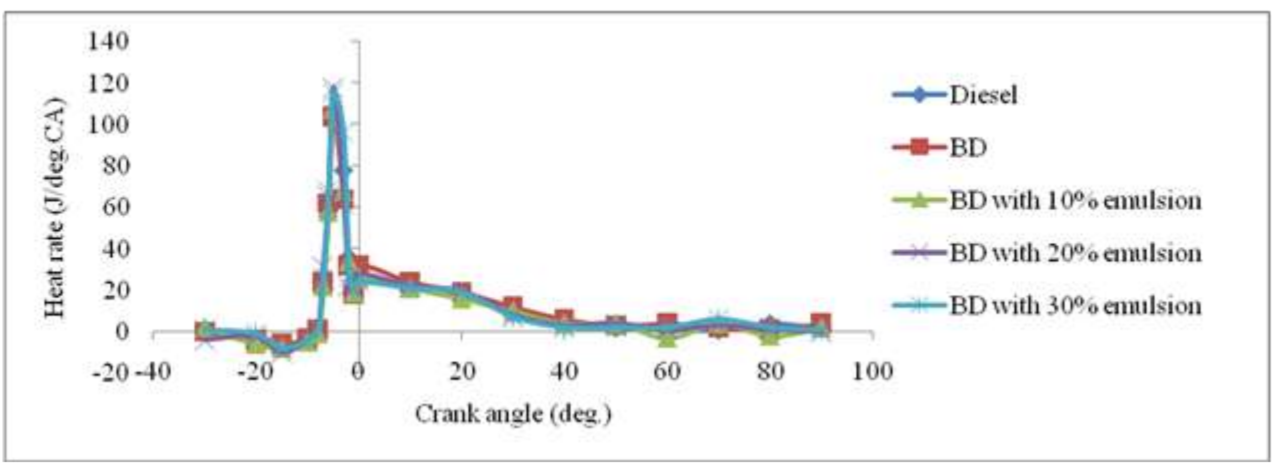

Figure 6:Variation of heat rate with crank

Emission characteristics angle

Carbon Monoxide (CO) Emission

The Figure 7 shows increase in the emission of carbon monoxide for all test fuels as the load increases. From the results it is found that the carbon monoxide emission for emulsified eucalyptus oil biodiesel is more when compared with diesel and biodiesel. Since the carbon monoxide emission depends the incomplete combustion of carbon containing substances.(19).The 30% emulsified biodiesel exhibits carbon monoxide emission nearly 0.32% volumes at its full load, whereas the carbon monoxide emission of diesel and biodiesel were found to be 0.068% volume respectively.

Unburned Hydrocarbon (UBHC) Emission

The Figure 8 shows that hydrocarbon emission of water emulsified eucalyptus oil biodiesel fuel is lower when compared with diesel and biodiesel fuel (20).Owing to the micro explosion phenomenon on the emulsified biodiesel, hydrocarbon emission reduces and the combustion process improves. The hydrocarbon emission of 30% water emulsified biodiesel shows 30% (32ppm) reduction in hydrocarbon emissions whereas diesel and biodiesel fuel shows 55ppm and 52ppm at full load respectively.

Nitrogen oxides (NO_x) Emission

The Figure 9 shows increase in the emission of nitrogen oxide for all test fuels at full load condition. The increase in emission of nitrogen oxide at full load is due to the presences of more oxygen molecules present in the fuel (21). It increases for diesel and biodiesel but from the results it is found to be decreasing for emulsified biodiesel at full load. The reason is low peak combustion temperature and the presence of water in the emulsified biodiesel which reduce the nitrogen oxide emission at full load. From the results it is found that the 30% water emulsified biodiesel fuel can cause 30% reduction in nitrogen oxide emission. The nitrogen oxide emissions of diesel and biodiesel fuel at full load are 496 ppm and 538ppm whereas for 30% water emulsified biodiesel it is 379 ppm respectively at full load.

Smoke Emission

The Figure 10 shows smoke emission of water emulsified eucalyptus oil biodiesel being considerable low when compared with biodiesel and diesel at full load. The reason for it is the vaporization of water from the emulsified fuel and increase in ignition delay period of the emulsified fuel, which in turn leads to faster combustion reaction and the reduction in smoke emission (22). The 30% emulsified biodiesel shows 32% reduction in smoke emission at full load.

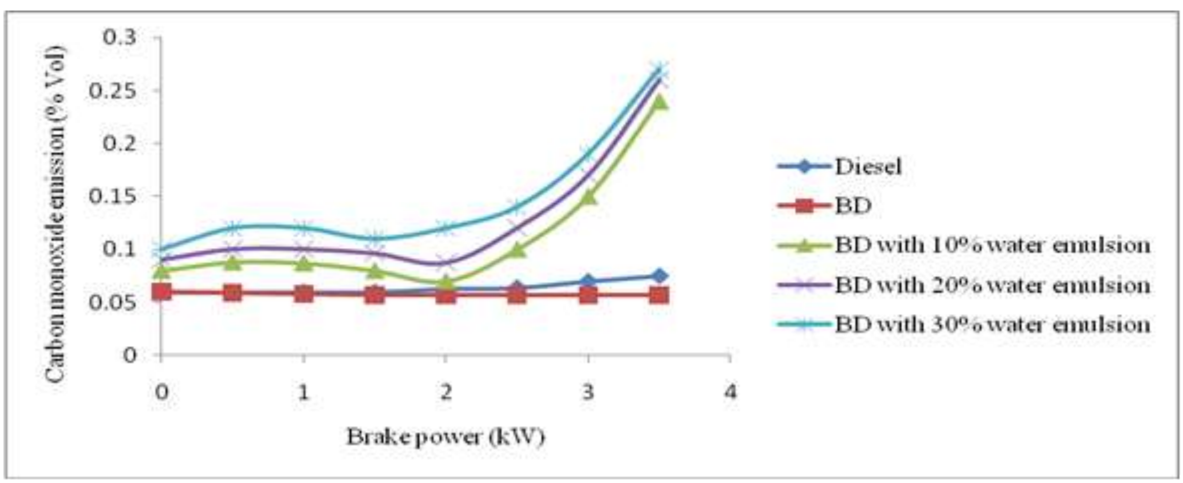

Figure7:Variation of carbon monoxide emission with brake power

ISSN: 2277-9655
Impact Factor: 4.116

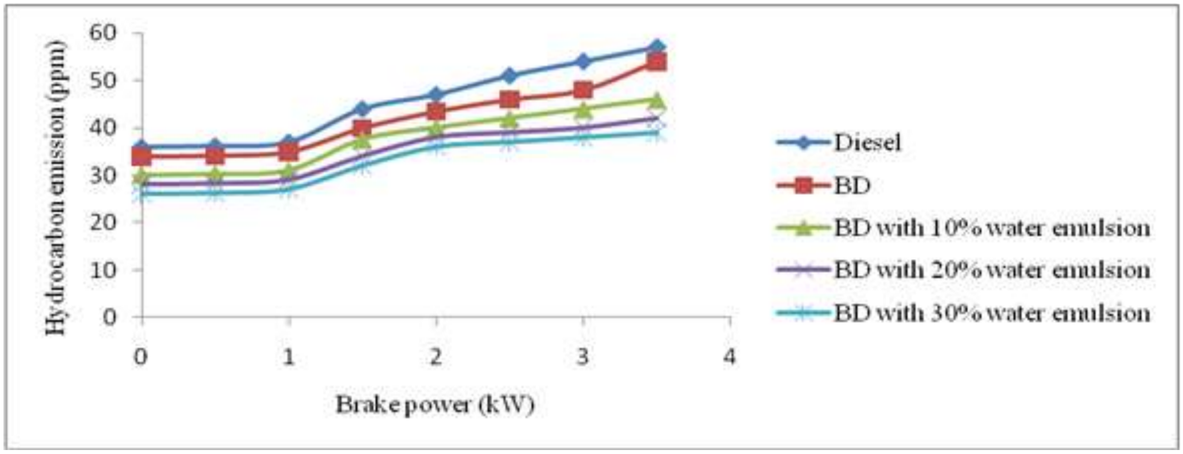

Figure 8:Variation of hydrocarbon emission with brake power

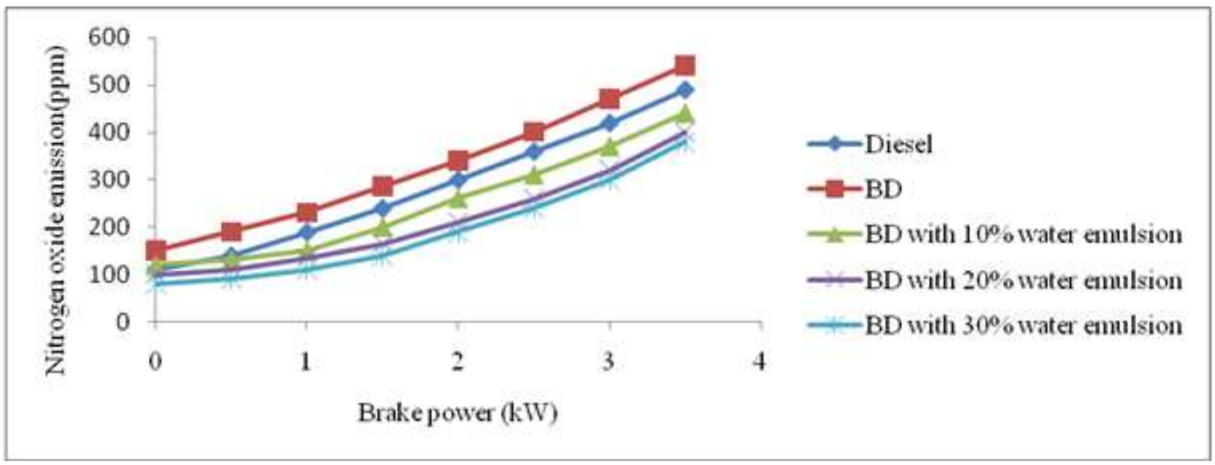

Figure 9:Variation of nitrogen oxide emission with brake power

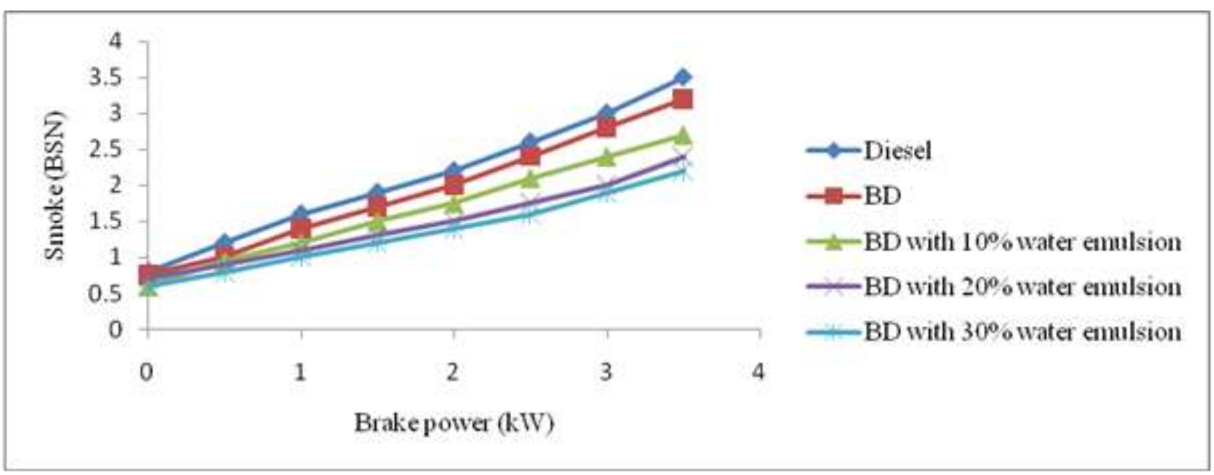

Figure 10:Variation of smoke emission with brake power

CONCLUSION

This paper reported a detailed study on the performance, combustion and emission characteristics of diesel engine with 10%, 20% and 30% water emulsified eucalyptus oil biodiesel and the results obtained were compared with the characteristics of diesel and biodiesel fuel. From the analyses the following conclusions were drawn:

1. The brake thermal efficiency increased by 7% for 20% water emulsified eucalyptus oil biodiesel when compared with diesel and biodiesel fuel.
2. The exhaust gas temperature decreased by 26% for 30% emulsified eucalyptus oil biodiesel when compared with other fuels at full load.
3. The Maximum values for peak pressure and heat release rate were observed for 30% water emulsified eucalyptus oil biodiesel compared with diesel and biodiesel fuel at full load.
4. The Carbon monoxide emission increased for all emulsified fuels, whereas hydrocarbon emission decreased by 30% for 30% water emulsified biodiesel.
5. The Nitrogen oxide (NOx) and smoke emission decreased by 30% and 32% respectively for 30% water emulsified eucalyptus oil biodiesel at full load compared with diesel and biodiesel fuel.

ACKNOWLEDGEMENT

The author expresses his deep gratitude to Department of Mechanical Engineering, Hindustan University for his valuable guidance and support in conducting this experimental research. Dr. V.P. Ramamoorthy, former professor of Anna University and present Managing Trustee of Dhanalakshmi College of Engineering and Ms.S.Nandhinisootchi deserves to be thanked profusely for his encouragement that led to the successful completion of this research.

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