THEVETIA PERUVIANA BIODIESEL EMULSION USED AS A FUEL IN A SINGLE CYLINDER DIESEL ENGINE REDUCES NOX AND SMOKE

by

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Biodiesel is a promising renewable alternative fuel for diesel. However, its adaptability is limited by its emission levels surpassing the existing emission norms. In this situation, it is essential to search for an economically apt way of reducing the pollutants so as to make biodiesel a viable proposition. Emulsified fuels have more priority in reducing Nitrogen Oxide (NOx) and smoke simultaneously than other fuels. In this study, Thevetia Peruviana biodiesel was emulsified with water in the ratios of 5%, 10%, 15% and 20% to investigate the engine performance and emission characteristics. Emulsified fuels showed an improvement in brake thermal efficiency accompanied by the drastic reduction in NOx. From the detailed study it was found that 15% water emulsified fuel showed the best performance and less emission than the other combinations.

Keywords: *Diesel Engine, Thevetia Peruviana biodiesel, biodiesel emulsions, Emissions*

1. Introduction

Diesel engines are indispensable but at the same time the depletion of non renewable sources of energy and strict emission regulations drive us to search for alternative fuels. In earlier days efforts have been taken to use straight vegetable oils as fuel in diesel engines. But the higher viscosity of vegetable oils restrict its use directly in to the diesel engines [1&2].So the vegetable oils are converted in to biodiesel using transesterification process. Biodiesel is a promising substitute fuel which gives reasonably satisfactory performance, reduced emissions and does not require any engine modifications [3]. Emissions like NO_x can be reduced either by retarding the injection timing or by including the exhaust gas recirculation (EGR) system. But this is accompanied by the increase in smoke and specific fuel consumption [4]. Water emulsified fuels are accorded more priority due to the simultaneous reduction of NO_x and smoke. Water can be mixed with the fuel using various methods such as 1.injection into the intake air 2. Direct injection into the cylinder, and, 3. Emulsification with water. No engine modification is required to use the emulsified fuel directly into the cylinder [5].Faster combustion reaction takes place in the water emulsified fuels due to the formation of micro explosion phenomenon. Thus Water emulsified fuels improve the combustion efficiency and the brake thermal efficiency and reduce the formation of NO_x, soot, hydrocarbon (HC) and particulate matter (PM) [6-9]. Micro explosion phenomenon is the process caused by the volatility differences between water and fuel. Emulsification process is a difficult one due to the immiscibility of water and fuel. Surfactant is added to overcome this difficulty and improve the stability for longer duration. The presence of surfactant is crucial for water fuel emulsion stability. It reduces the interfacial tension between water and fuel and stabilizes the emulsion for long hours [10]. Of late investigation in the field of biodiesel water emulsion has gained interest among researchers. This study deals with the performance and the emission characteristics of diesel engine using emulsified biodiesel as fuel with water in the ratios of 5%, 10%, 15% and 20%. Biodiesel (BD) is prepared from the seed oil of Thevetia Peruviana plant called yellow oleander. Emulsified biodiesel improved the trade-off relation between NOx concentration and smoke density over that of diesel emulsion [11]. However the emulsification stability of O/W/O biodiesel emulsion is inferior to that that of the O/W/O diesel emulsion if the same surfactant mixture of span 80 and tween 80 is used [12]. To overcome this constraint an emulsification unit was setup in the laboratory and stirring was continued till the completion of the experiment. The Emulsion was prepared using the emulsifying agent liphophilic span 80 having the HLB value of 4.3 in 0.5% of total volume. The addition of increasing volume of emulsifying agent increases the stability of emulsion but emit more CO, HC and Smoke [13]. Keeping this in mind, it was decided to restrict the emulsifying agent to 0.5% by volume but stirring to be continued till the end. In the first step, the required quantity of biodiesel and emulsifying agent were added in the fuel tank and stirred for the first ten minutes in 8000 rpm. Then the specified quantity of water was added and the stirring was continued at 3000 rpm. Using these emulsions, the diesel engine performance and emission characteristics were studied.

2. Experimental details

A computerized kirloskar diesel engine of AV_1 model, four stroke, direct injection, naturally aspirated, water cooled engine was utilized to investigate this study. The experimental set up is shown in fig. 1.

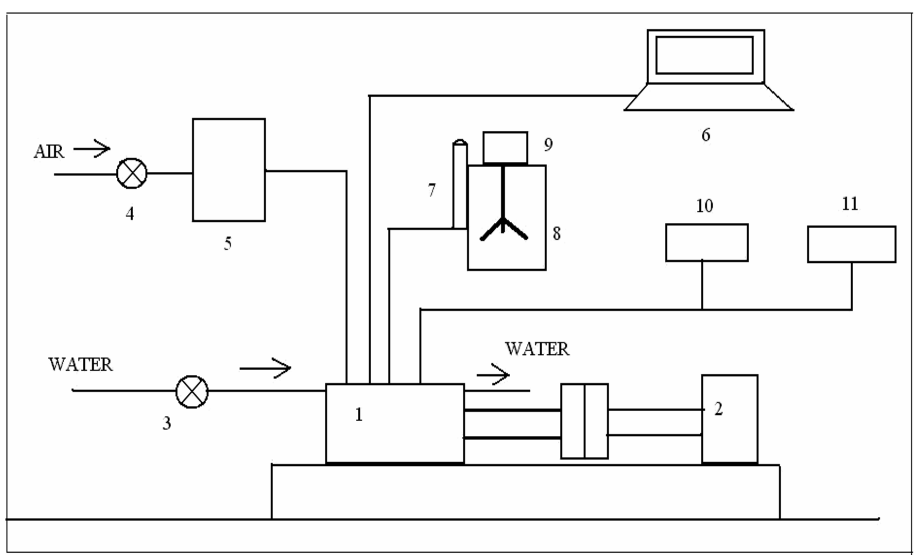

Figure 1. **Experimental Set up -** 1.Engine 2.Dynamometer 3.Water flow meter 4.Manometer 5. Air tank 6.Data acquisition system 7. Burette 8. Fuel Tank 9. Motor with Stirrer 10. Smoke meter 11.Gas Analyzer

The diesel engine was coupled with an eddy current dynamometer and a data acquisition system so that the data can be saved. A piezo electric pressure transducer is used to obtain pressure crank angle diagram. The pressure transducer is flush mounted adjacent to the injector .Fuel flow rates are obtained with calibrated burette.AVL Digas 444 type gas analyzer to measure CO, CO_2, HC, O_2 and NO and AVL 437C smoke meter were utilized to find the constituents and smoke opacity of exhaust gas. Inlet and outlet water temperatures and air and exhaust gas temperatures are measured using k type thermocouples.

The engine specifications are listed in Tab. 1.

Table 1. Specification of the diesel engine

No. of cylinders	1
Bore	80 mm
Stroke	110mm
Compression ratio	16.5:1
Rated power	3.7 Kw
Injection pressure	200-205 bar
Injection timing	27^0 BTDC static (diesel)
Rated speed	1500 rpm

Brake thermal efficiency (BTE) of diesel engine in various injection timings have been found out using biodiesel as fuel. BTES of 29.1%, 28.8%, 28.5% were observed in the injection timings of 27˚,25˚ and 23˚ respectively. In view of higher efficiency, 27˚ injection timing was preferred in this study.

Biodiesel was prepared in the laboratory using the seed oil of the Thevetia Peruviana plant. 5g of NaoH per litre of oil was mixed with 160 ml of methyl alcohol to produce methoxide. Oil was heated to 60^0C and the prepared methoxide was poured into the oil. The reaction was allowed for one hour and the final products were allowed to settle in the separating funnel overnight. Using distilled water, the biodiesel was washed four or five times to remove the impurities. The properties of biodiesel are listed in Tab. 2. given below:

Table 2: Properties of biodiesel

Viscosity	6.0(Cst)
Density	860(kg/ $m^{3)}$
Flash point	160(̊C)
Fire point	172(̊C)
Calorific Value	41032 (kJ/kg)

Water was added in the ratios of 5%, 10%, 15% and 20% with biodiesel by volume and emulsified. The properties of emulsified fuels are given below in Tab. 3.

Table 3: Properties of emulsified fuels

Type of fuel	Density kg/ m^3	Calorific value kJ/ kg
Diesel	830	42500
Biodiesel	860	41032
Biodiesel +5%W	867	38665
Biodiesel +10%W	874	36337
Biodiesel +15%W	881	34046
Biodiesel +20%W	888	31791

The experiments were conducted in different loads like 25%, 50% and 75% of full load and full load. Similar experiments were done with diesel and biodiesel so as to make a comparison.

3. Results and discussions

3.1 Brake Thermal Efficiency (BTE)

The variations of brake thermal efficiencies at different loads for various combinations have been shown in fig. 2. Brake thermal efficiency increases with the increase in load. The brake thermal efficiency of biodiesel is less than that of diesel due to its lower calorific value. Most of the water emulsified fuels exhibit lower brake thermal efficiencies in low loads compared to diesel and biodiesel and show slight improvement in higher loads with respect to biodiesel. This is because the micro explosion phenomenon, due to volatility difference between water and fuels, enhances air fuel mixing during higher engine torque and hence the improvement in combustion efficiency [8]. This could be the possible reason for higher brake thermal efficiencies even though the calorific values of the emulsions are less than that of biodiesel. The BTE of 15% emulsified biodiesel is 6.87% higher than that of biodiesel at full load and 10% emulsified biodiesel shows an increase of 2.4%.Even when compared to diesel a slight improvement of 2.64% in BTE is observed for 15% emulsified biodiesel.

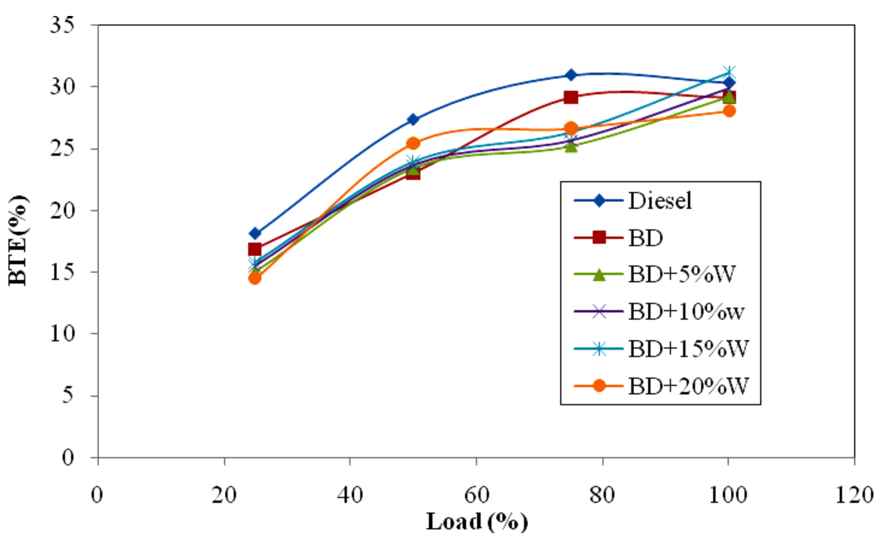

Figure 2. Brake Thermal Efficiency versus Load

3.2 Exhaust Gas Temperature

The exhaust gas temperature (EGT) increases while the load is increased. The EGT of biodiesel is higher than that of diesel. The heavier molecules of biodiesel lead to continuous burning even during exhaust which causes higher exhaust gas temperature [14] and for emulsified fuels, the exhaust gas temperatures are observed to be lesser than that of biodiesel This is because the water in the emulsion gets vaporized during the combustion process and absorbs the heat energy which decreasing the local adiabatic flame temperature [8]. This leads to lower exhaust gas temperatures than those of biodiesel as shown in fig. 3.

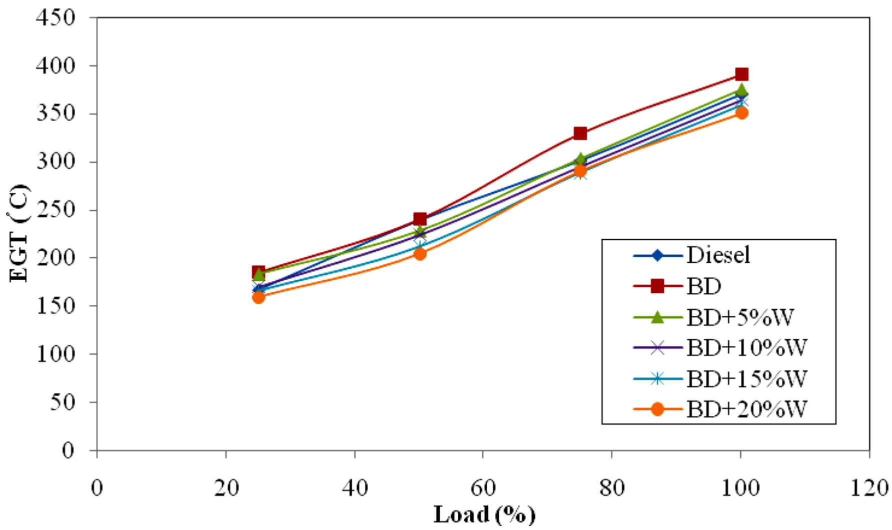

Figure 3. Exhaust Gas Temperature versus Load

3.3 Hydro Carbon (HC) Emissions

The hydro carbon emissions at different loads for different fuels have been shown in fig. 4. The higher oxygen content of biodiesel leads to more complete burning than diesel fuel [14].

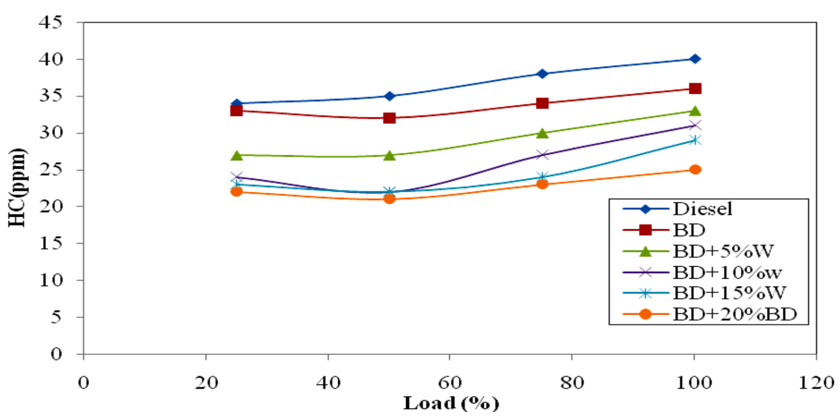

Figure 4. Hydro Carbon versus Load

So biodiesel shows reduction in HC emissions than those shown by diesel. HC emissions of emulsified fuels are found to decrease to a level less than those in biodiesel. This is because the enhancement of air fuel mixing due to micro explosion phenomenon, as discussed, improves the combustion process and hence the reduction of HC emissions. 20% emulsified biodiesel shows 3.05% HC reduction than in biodiesel, whereas 1.94% reduction is observed for 15% emulsified biodiesel at full load.

3.4 Nitrogen Oxide (NOx) Emissions

NOx emission increases while the load is increased. In the case of biodiesel, since burning continues even during exhaust, due to the heavier molecules of biodiesel, exhaust gas temperature increases as has been seen already, higher content of NOx is observed compared to diesel [14]. By oxidation, the atmospheric nitrogen forms NOx at sufficiently high temperatures [15]. NOx emissions of emulsified fuels are found decreasing than in diesel and biodiesel as shown in fig. 5.

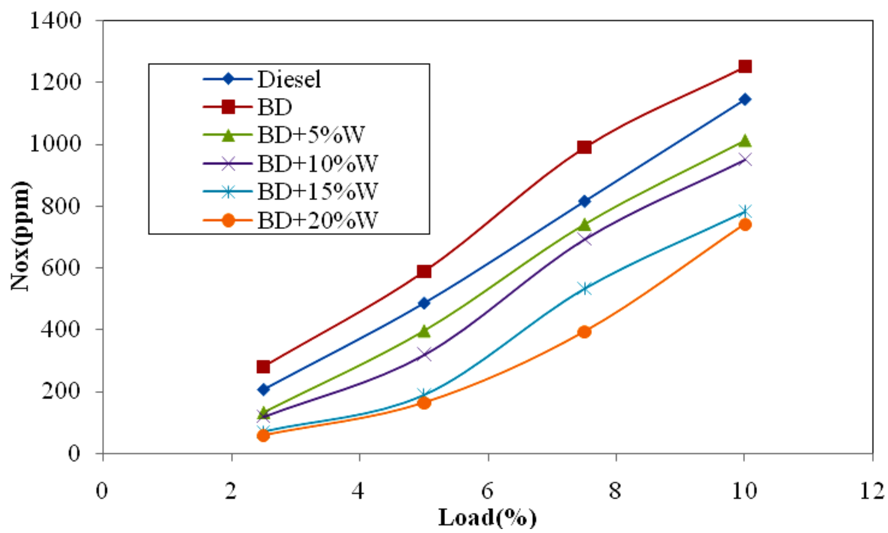

Figure 5. Nitrogen Oxide versus Load

This is because the lower adiabatic flame temperature, due to the presence of water in the emulsified fuels, reduces the formation of NOx [16]. 20% emulsified biodiesel shows 41% NOx reduction than in biodiesel, whereas 38% reduction is observed for 15% emulsified biodiesel at full load.

3.5 Smoke opacity

The smoke opacity at different loads for various fuels has been shown in fig. 6. The smoke opacity of biodiesel is higher than the smoke opacity of diesel due to the heavier molecules of biodiesel [14]. Water emulsified fuels show considerable reduction in smoke opacity compared to biodiesel. This is because water gets vaporized by absorbing the heat energy during combustion process. This increases the ignition delay period of emulsified fuels. The ignition delay period of 15% and 20% emulsified fuels were 12.3 degrees and 12.9 degrees respectively while that for biodiesel is 10.1 degrees This increase in delay period improves the mixing process which leads to faster combustion reaction and hence the reduction of smoke opacity. 20% emulsified biodiesel shows 9.63% smoke opacity reduction than biodiesel; whereas 7.22% of reduction is observed for 15% emulsified biodiesel at full load.

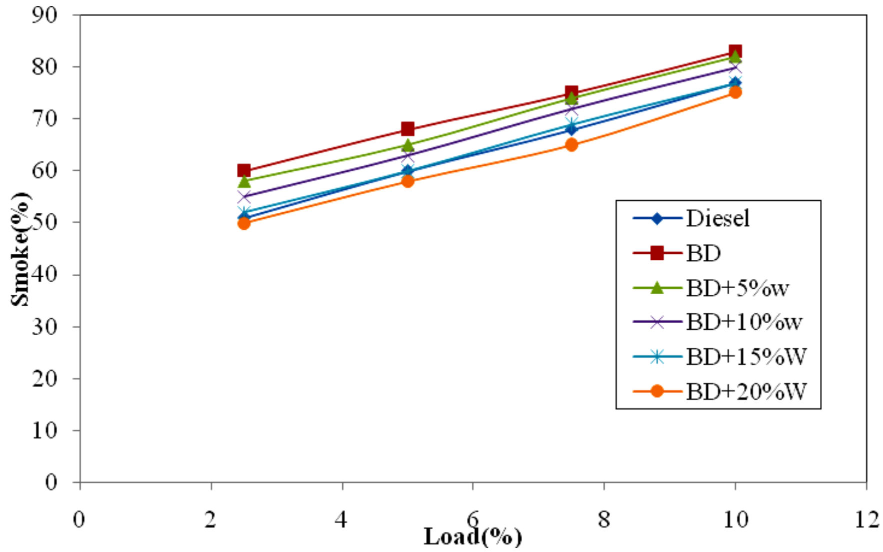

Figure 6. Smoke opacity versus load

3.6 Cylinder pressure and Heat release rate

The pressure and heat release rate for various crank angles have been shown in figs. 7 &8.

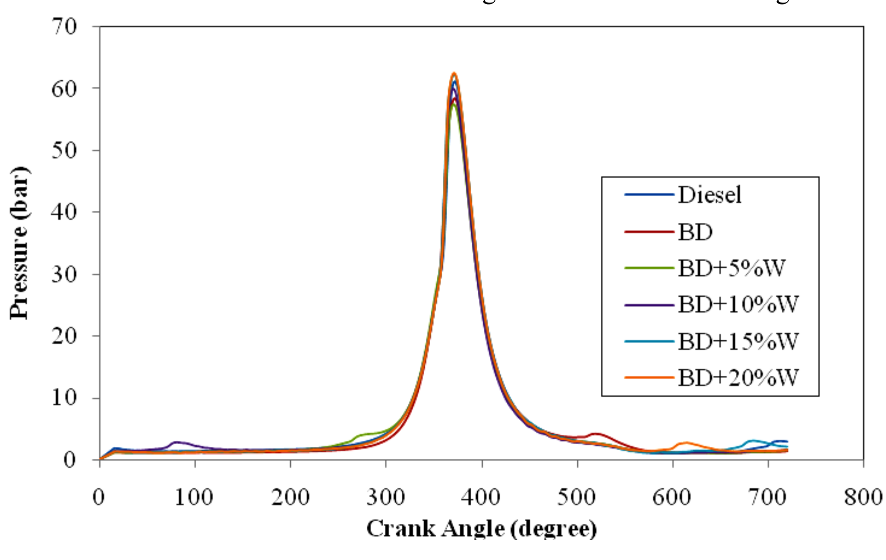

Figure 7. Pressure versus Crank angle

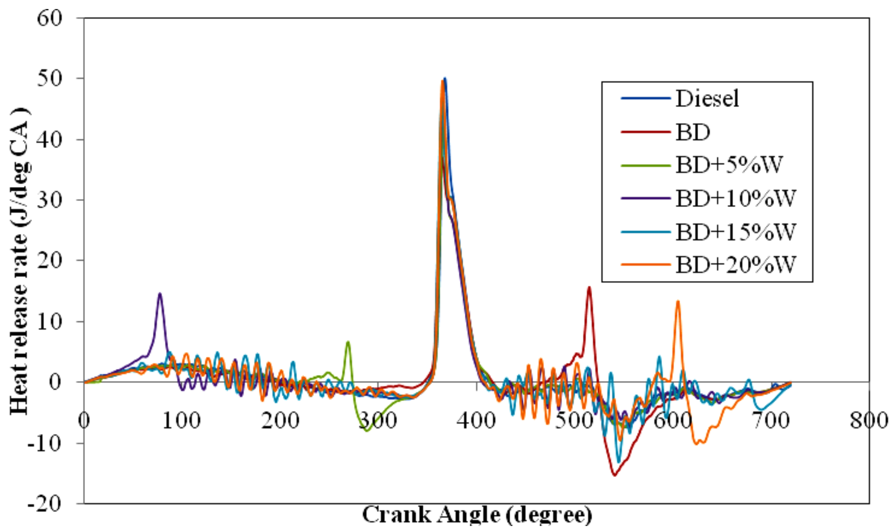

Figure 8. Heat release rate versus Crank angle

20% and 15 % emulsified biodiesel fuels show higher peak pressure and heat release rate than other fuel combinations in full load. The vaporization of water created higher ignition delay period in emulsified fuels as compared to neat fuels. The ignition delay period affects the peak pressure and heat release rate [17]. The higher ignition delay period increases the premixed combustion period for emulsified fuels. The ignition delay period is one that the fuel is getting ready for chemical and physical preparation for combustion. So the emulsified fuels needed less compression work than other fuels during the compression stroke. This leads to higher peak pressure during expansion stroke .Due to the increase in ignition delay period more amount of fuel is burned, thus increases the heat release rate in the premixed burning [6&18] .

4. Conclusions

1. 15% emulsified biodiesel showed 6.87% increase in BTE compared to biodiesel, 10% emulsified biodiesel showed 2.4% increse whereas 20% emulsified biodiesel showed 3.78% less compared to biodiesel at full load.
2. Reduction of 41% in NOx emissions was found for 20% emulsified biodiesel and 38% reduction for 15% emulsified biodiesel at full load.
3. 20% emulsified biodiesel showed 3.05% HC reduction than in biodiesel, whereas 1.94% reduction was observed for 15% emulsified biodiesel at full load.
4. 9.63% reduction in smoke opacity was observed for 20% emulsified biodiesel and a 7.22% reduction for 15% emulsified biodiesel.
5. It was observed that 20% and 15 % water emulsified biodiesels showed higher peak pressure and heat release rates than the other combinations.
6. From the detailed study, it was observed that 15% emulsified biodiesel showed both best performance and emission reduction than other fuel combinations in full load.

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