



Experimental Investigation of a Diesel Engine fueled by emulsified B20 biodiesel

R. Vinoth Kumar

Department of Mechanical Engineering, E.S.Engineering College, Villupuram, Tamil Nadu, India.

Abstract : The depletion of petroleum reserves and ever growing vehicle population have lead to the search for an apt substitute fuel to meet the future requirements satisfying the emission norms as well. Since diesel engines emit gases like nitrogen oxide (NO_x) and particulate matter to objectionable level which are harmful to the environment, the search becomes much more relevant. Emulsified fuels have been found to be promising in reducing the emissions. Thevetia Peruviana biodiesel has already been found to be a promising substitute fuel for diesel. In this study B20 biodiesel of Thevetia Peruviana (diesel and 20% biodiesel) with water in the ratios of 5% and 7.5% has been utilized as fuel to investigate the engine performance and emission characteristics and the results reported.

Keywords : B20 biodiesel, Thevetia Peruviana biodiesel, emulsions, surfactants, emissions.

I. Introduction

The depletion of petroleum reserves due to the growing vehicle population has intensified the search for renewable alternate fuels. The emissions like NO_x and particulate matter from the diesel engines are detrimental to the environment and to the human beings. Water emulsified fuels are getting importance due to the simultaneous reduction of NO_x and particulate matter. The addition of water in the form of emulsion has been found to improve the combustion efficiency and the brake thermal efficiency [1&2]. Analysis of the emissions and heat release data indicate that water enhances air fuel mixing to maintain fuel economy and lower soot emissions [3]. The volatility difference between fuel and water enhances the micro explosion phenomenon which leads to faster combustion reaction. So there is an improvement in brake thermal efficiency and reduction in the formation of NO_x, Soot, HC and PM in the diesel engine [4&5]. Usually diesel or biodiesel is immiscible with water. Surfactants are required to emulsify the fuel and ensure stability for long duration by reducing the interfacial tension [6]. In utilizing span 80 and tween 80 in producing O/W/O three phase emulsion, 2% emulsifier with a HLB=6-8 produces more stable emulsifier [7]. Many recent papers highlight the engine performance and emission reduction in using the water emulsified diesel as fuel. Research on biodiesel emulsion is limited compared to diesel emulsion due to stability problems. The emulsification stability of biodiesel is inferior to that of the diesel emulsion if the same surfactant mixture of span 80 and tween 80 is used [8]. The increase of water content in the emulsion formulation reduces the calorific value of the fuel[9]. The

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present study deals with the performance and emission characteristics of the diesel engine using B20biodiesel with the emulsions of 5% and 7.5% water. B20biodiesel was used in the above combination due to its suitability as an alternative fuel for diesel as stated in most of the research works [10]. The low energy content restricts the utilization of high percentage of water in emulsified fuel. Hence in this study emulsified fuels in low percentages of water have been tried. These biodiesel emulsions have emulsification stability for five hours.

II. Experimental Details

A computerized kirloskar diesel engine of AV1 model, four stroke, direct injection, naturally aspirated, water cooled engine was utilized for the investigation. The engine specifications are listed in Table 1.

Table I Specification of the diesel engine

No. of cylinders	1
Bore	80mm
Stroke	110mm
Compression ratio	16.5:1
Rated power	3.7kW
Injection pressure	200-205 bar
Injection timing	23° BTDC
Rated speed	1500rpm

The diesel engine in which the experiments were carried out was coupled with an eddy current dynamometer and a data acquisition system. A five gas AVL analyzer was used to measure the emission characteristics like CO₂, CO, NO_x, HC and O₂. Smoke opacity was measured using the AVL smokemeter. Thevetia Peruviana biodiesel (TPBD) was prepared in the laboratory using the seed oil of the plant. 5g of NaOH per liter of Thevetia Peruviana seed oil (TPSO) was mixed with 160 ml of methyl alcohol to prepare methoxide. Then oil was heated to 60°C 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 Table 2.

Table 2 Properties of Biodiesel

Properties	diesel	TPSO	TPBD	ASTM code
viscosity (Cst), 40°C	4.0	32.9	6.0	D2217
specific gravity	0.830	0.920	0.860	D445
Flash Point°C	45	240	160	D92
Fire point (°C)	52	252	172	D92
Cloud point (°C)	-8	2	-2	D97
Pour point (°C)	-20	-3	-4	D97
Calorific value (kj/kg)	43200	40100	41032	D4809
Cetane	49	47	50	D4737

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Emulsions were prepared by using the emulsifying agents lipophilic span 80 and hydrophilic tween 80 having the HLB value of 8 in 2% of total volume. In this study a two stage emulsification method was used for the emulsion preparation. In the first stage lipophilic span 80 with HLB = 4.3 and hydrophilic tween 80 with HLB=15 were added with diesel and water slowly and stirred. In the second stage biodiesel was added and the stirring was continued for 10 minutes at 5000rpm. Water was added in the ratios of 5% and 7.5% with B20biodiesel by volume. The properties of emulsified fuels are given in table 3 below. Using the emulsions the engine was run and the performance and emission characteristics were studied.

Table 3 Properties of Emulsified Fuels

Type of fuel	Density kg/m ³	Calorific value kj/kg
Diesel	836	42500
B20 Biodiesel	836	42198
B20 Biodiesel +5%W	845	39700
B20 Biodiesel +7.5%W	848	38466

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. The accuracy of measurement and uncertainties of computed results are listed in Table 4.

Table 4 The Accuracies of the Measurements and the Uncertainties in the Calculated Results

Measurements	Accuracy
Temperatures	±1°C
Speed	±1rpm
Time	±0.5%
Smoke meter	±1%
CO	±0.3% vol
CO ₂	±0.5% vol
HC	± 10rpm vol
O ₂	±0.1% vol
No	±50 ppm vol
Pressure	±0.2%
Crank angle	±0.5deg
Calculated Results	Uncertainty
Thermal efficiency	±1%
Time	±0.5%
Fuel volumetric rate	±1%

III. Results and Discussions

A. Brake Thermal Efficiency (BTE)

The variations of brake thermal efficiency with different loads for different fuels have been shown in figure 1. The brake thermal efficiency increases with increase in load. The brake thermal efficiency of B20 biodiesel is less than diesel due to its lower calorific value. The 5% and 7.5% water emulsified fuels exhibit lower brake thermal efficiencies in low loads compared to diesel and show slight improvement in higher loads. 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 [4]. This could be the possible reason for higher brake thermal efficiencies even though the calorific values of the emulsions are

less than that of diesel. The BTE of 7.5% water emulsion is 3% higher than pure diesel at full load, and it is 2.3% higher for 5% water emulsion.

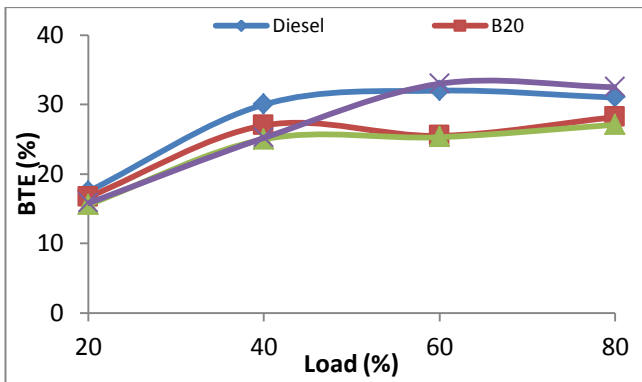


Fig.1 Brake Thermal Efficiency versus Load

B. Exhaust Gas Temperature

The exhaust gas temperature increases while the load is increased. The EGT of B20 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. For emulsions the exhaust gas temperatures are lesser than that of diesel. This is because the water content in the emulsions gets vaporized during the combustion process and absorbs the heat energy which decreases the local adiabatic flame temperature [4]. This leads to lower exhaust gas temperatures than that of diesel as shown in figure 2. The EGT of B20 biodiesel is 449°C whereas for diesel it is 429°C only. But 7.5% water emulsion and 5% water emulsion emit the exhaust gas with the temperatures of 412°C and 420°C respectively.

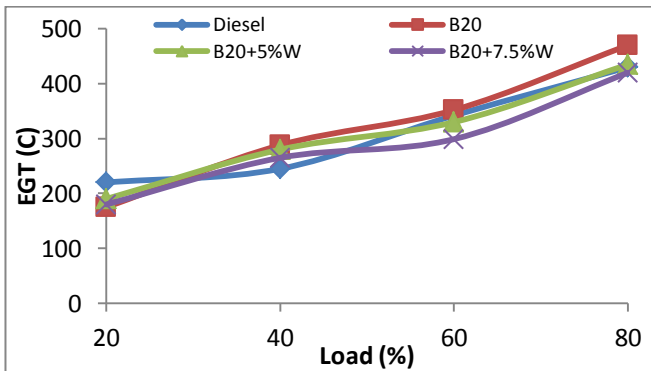


Fig. 2 Exhaust Gas Temperature versus Load

C. Hydro Carbon (HC) Emissions The hydro carbon emissions at different loads for different fuels have been shown in figure 3.

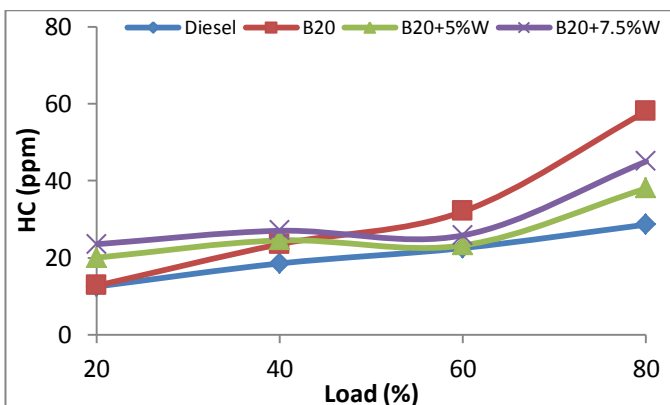
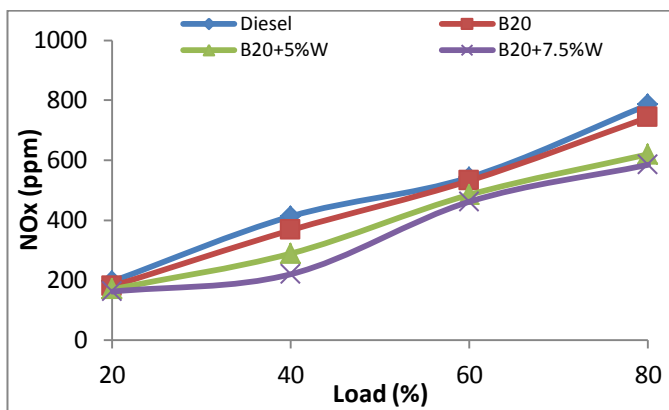


Fig.3 Hydro Carbon versus LoadB20

Biodiesel shows significant reduction in HC emissions due its efficient burning than diesel. HC emissions of emulsions are found decreasing than that of diesel in higher loads. This is because the enhancement of air fuel mixing due to micro explosion phenomenon as discussed already improves the combustion process and hence the reduction of HC emissions.

D. Nitrogen Oxide (NOx) Emissions

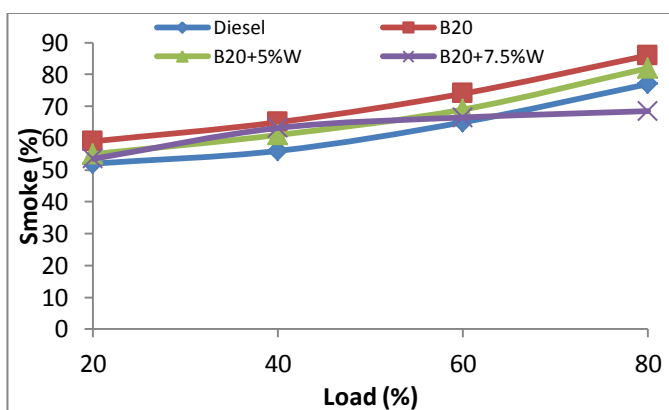
NOx emission increases while the load is increased as shown in figure 4. In case of B20 biodiesel, burning continuous even during exhaust due to the heavier molecules of biodiesel and exhaust temperature increases as seen already and this is the cause for slightly higher content of NOx compared to diesel[11].

**Fig .4 Nitrogen Oxide versus Load**

By oxidation, the atmospheric nitrogen forms NOx at sufficiently high temperatures [12]. NOx emissions of emulsions are found decreasing than that of diesel as shown in figure 4. This is because the existence of lower adiabatic flame temperature due to the presence of water in the emulsions reduces the formation of NOx [13]. 7.5% water emulsion shows 10% NOx reduction than that of diesel, whereas 8%reduction is observed for 5% water emulsion at full loads.

E. Smoke opacity

The smoke opacity at different loads for different fuels has been shown in figure 5. The smoke opacity of B20 biodiesel is slightly higher than that of diesel due the heavier molecules of biodiesel.

**Fig.5 Smoke opacity versus load**

Water emulsified fuels are found to produce reduced smoke opacity compared to diesel. This is because water gets vaporized by absorbing the heat energy during combustion process. This increases the ignition delay time [14]. The ignition delay times of 5% and 7.5% emulsified fuels were found to be 14.2 degrees and 14.4

degrees respectively whereas diesel had a delay of 13.6 degrees. This increase in delay time improves the mixing process which leads to improved combustion reaction and hence the reduction of smoke opacity[4]. 7.5% water emulsion shows 5% smoke opacity reduction than that of diesel, where as 2.5% reduction is observed for 5% water emulsion at full load.

IV. Conclusions

1. Thevetia Peruviana biodiesel was prepared in the laboratory and it was observed that the properties were comparable to that of diesel.
2. Emulsified B20 biodiesel (diesel and 20% biodiesel) with water in the ratios of 5% and 7.5% have been prepared and utilized as fuels
3. B20 biodiesel showed slightly lesser BTE compared to diesel due to its lower calorific value. But water emulsified fuels were found to increase the BTE compared to that of diesel at full load.
4. The continuous burning of B20 biodiesel even during exhaust led to the formation of higher EGT and hence increased NO_x emissions than diesel. But emulsified fuels exhibited lower exhaust gas temperatures and hence reduced NO_x emissions. A reduction of 10% in NO_x emissions was found for 7.5% water emulsified fuel and 8% reduction for 5% water emulsified fuel.
5. Significant reduction in HC emissions was noted for B20 biodiesel due to its efficient burning than diesel. In the case of emulsified fuels, enhancement of air fuel mixing during micro explosion phenomenon in higher loads improved the combustion process thereby reducing the HC emissions.
6. The smoke opacity of B20 biodiesel was slightly higher than that of diesel due to the heavier molecules of biodiesel. Emulsified fuels showed reduction in smoke opacity. This was due to the faster combustion reaction. 5% reduction in smoke opacity was noted for 7.5% water emulsified fuel, and 2.5% reduction for 5% water emulsified fuel.
7. There is no significant difference in pressure and heat release rates for various fuels.

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