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Experimental Investigation of a Diesel Engine fueled with emulsified biodiesel

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Abstract: The depletion of petroleum reserves and ever growingvehicle population have lead to the search for an apt substitute fuel tomeet the future requirements satisfying the emission norms as well.Since diesel engines emit gases like nitrogen oxide (NOx) andparticulate matter to objectionable level which are harmful to theenvironment, the search becomes much more relevant. Emulsifiedfuels have been found to be promising in reducing the emissions.
ThevetiaPeruviana biodiesel has already been found to be apromising substitute fuel for diesel. In this study B20 biodiesel ofThevetiaPeruviana (diesel and 20% biodiesel) with water in the ratiosof 5% and 7.5% has been utilized as fuel to investigate the engineperformance and emission characteristics and the results reported.
Keywords : B20 biodiesel, ThevetiaPeruviana biodiesel, emulsions,surfactants, emissions.

I. Introduction

The depletion of petroleum reserves due to the growingvehicle population has intensified the search for renewablealternate fuels. The emissions like NOxand particulate matterfrom the diesel engines are detrimental to the environment andto the human beings. Water emulsified fuels are gettingimportance due to the simultaneous reduction of NOx andparticulate matter. The addition of water in the form ofemulsion has been found to improve the combustionefficiency and the brake thermal efficiency [1&2]. Analysis ofthe emissions and heat release data indicate that waterenhances air fuel mixing to maintain fuel economy and lowersoot emissions [3]. The volatility difference between fuel andwater enhances the micro explosion phenomenon which leadsto faster combustion reaction. So there is an improvement inbrake thermal efficiency and reduction in the formation ofNOx, Soot, HC and PM in the diesel engine [4&5]. Usuallydiesel or biodiesel is immiscible with water. Surfactants arerequired to emulsify the fuel and ensure stability for longduration by reducing the interfacial tension [6]. In utilizingspan 80 and tween 80 in producing O/W/O three phaseemulsion, 2% emulsifier with a HLB=6-8 produces morestable emulsifier [7]. Many recent papers highlight the engineperformance and emission reduction in using the wateremulsified diesel as fuel. Research on biodiesel emulsion islimited compared to diesel emulsion due to stability problems.The emulsification stability of biodiesel is inferior to that ofthe diesel emulsion if the same surfactant mixture of span 80and tween 80 is used [8]. The increase of water content in theemulsion formulation reduces the calorific value of the fuel[9]. The present study deals with the performance andemission 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 itssuitability as an alternative fuel for diesel as stated in most ofthe research works [10]. The low energy content restricts theutilization of high percentage of water in emulsified fuel.Hence in this study emulsified fuels in low percentages ofwater have been tried. These biodiesel emulsions haveemulsification stability for five hours.

II. Experimental Details

A computerized kirloskar diesel engine of AV1 model, fourstroke, direct injection, naturally aspirated, water cooledengine was utilized for the investigation. The enginespecifications are listed in Table 1.

Table I Specification of the diesel engine

No. of cylinders 1	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 outwas coupled with an eddy current dynamometer and a dataacquisition system. A five gas AVL analyzer was used tomeasure the emission characteristics like CO2, CO, NOx, HCand O2. Smoke opacity was measured using the AVL smokemeter. ThevetiaPeruviana biodiesel (TPBD) was prepared inthe laboratory using the seed oil of the plant .5g of NaoH perliter of ThevetiaPeruviana seed oil (TPSO) was mixed with160 ml of methyl alcohol to prepare methoxide. Then oil washeated to 600C and the prepared methoxide was poured intothe oil. The reaction was allowed for one hour and the finalproducts were allowed to settle in the separating funnelovernight. Using distilled water, the biodiesel was washedfour or five times to remove the impurities. The properties ofbiodiesel are listed in Table 2.

Table 2 Properties of Biodiesel

Properties kinematic	**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 number	49	47	50	D4737

Emulsions were prepared by using the emulsifying agentslipophilic span 80 and hydrophilic tween 80 having the HLBvalue of 8 in 2% of total volume. In this study a two stageemulsification method was used for the emulsion preparation.In the first stage lipophilic span 80 with HLB = 4.3 andhydrophilic tween 80 with HLB=15 were added with dieseland water slowly and stirred. In the second stage biodiesel wasadded 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 aregiven in table 3 below. Using the emulsions the engine wasrun and the performance and emission characteristics werestudied.

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 experimentswere done with diesel and biodiesel so as to make acomparison. The accuracy of measurement and uncertaintiesof 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 loadsfor different fuels have been shown in figure 1. The brakethermal efficiency increases with increase in load. The brakethermal efficiency of B20 biodiesel is less than diesel due toits lower calorific value. The 5% and 7.5% water emulsifiedfuels exhibit lower brake thermal efficiencies in low loadscompared to diesel and show slight improvement in higherloads. This is because the micro explosion phenomenon due tovolatility difference between water and fuels enhances air fuelmixing during higher engine torque and hence theimprovement in combustion efficiency [4]. This could be thepossible reason for higher brake thermal efficiencies eventhough the calorific values of the emulsions are less than thatof diesel. The BTE of 7.5% water emulsion is 3% higher thanpure diesel at full load, and it is 2.3% higher for 5% wateremulsion.

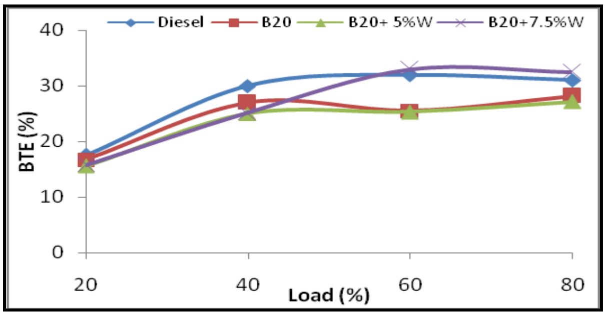

Fig.1 Brake Thermal Efficiency versus Load

B. Exhaust Gas Temperature

The exhaust gas temperature increases while the load isincreased. The EGT of B20 biodiesel is higher than that ofdiesel. The heavier molecules of biodiesel lead to continuousburning even during exhaust which causes higher exhaust gastemperature. For emulsions the exhaust gas temperatures arelesser than that of diesel. This is because the water content inthe emulsions gets vaporized during the combustion processand absorbs the heat energy which decreases the localadiabatic flame temperature [4]. This leads to lower exhaustgas temperatures than that of diesel as shown in figure 2. TheEGT of B20 biodiesel is 449°C whereas for diesel it is 429°Conly. But 7.5% water emulsion and 5% water emulsion emitthe exhaust gas with the temperatures of 412°C and 420°Crespectively.

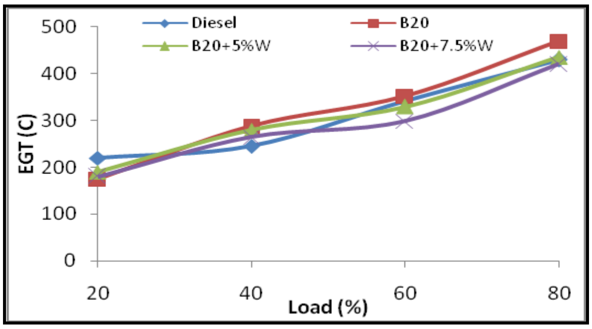

Fig. 2 Exhaust Gas Temperature versus Load

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

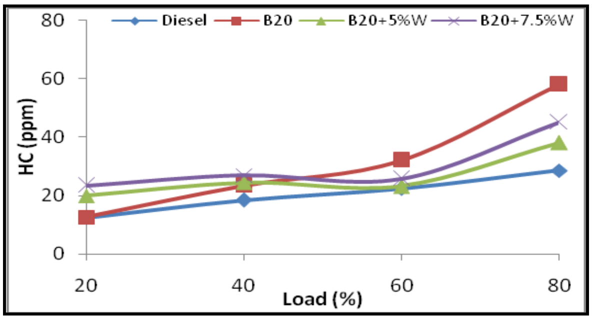

Fig.3 Hydro Carbon versus LoadB20

Biodiesel shows significant reduction in HC emissionsdue its efficient burning than diesel. HC emissions ofemulsions are found decreasing than that of diesel in higherloads. This is because the enhancement of air fuel mixing dueto micro explosion phenomenon as discussed alreadyimproves the combustion process and hence the reduction ofHC emissions.

D. Nitrogen Oxide (NOx) Emissions

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

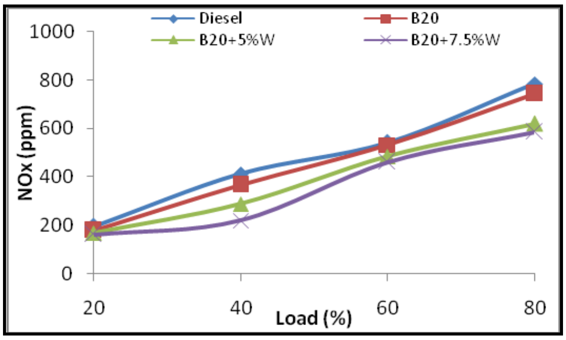

Fig .4Nitrogen Oxide versus Load

By oxidation, the atmospheric nitrogen forms NOx atsufficiently high temperatures [12]. NOx emissions ofemulsions are found decreasing than that of diesel as shown infigure 4. This is because the existence of lower adiabatic flametemperature due to the presence of water in the emulsionsreduces the formation of NOx [13]. 7.5% water emulsionshows 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 hasbeen shown in figure 5.The smoke opacity of B20 biodiesel isslightly higher than that of diesel due the heavier molecules ofbiodiesel.

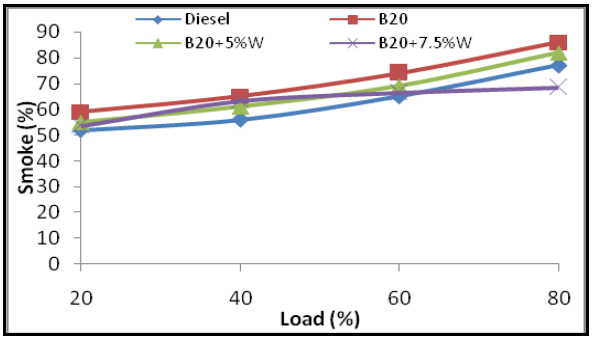

Fig.5 Smoke opacity versus load

Water emulsified fuels are found to produce reduced smokeopacity compared to diesel. This is because water getsvaporized by absorbing the heat energy during combustionprocess. This increases the ignition delay time [14]. Theignition delay times of 5% and 7.5% emulsified fuels werefound to be 14.2 degrees and 14.4 degrees respectively whereas diesel had a delay of 13.6 degrees. This increase in delaytime improves the mixing process which leads to improvedcombustion reaction and hence the reduction of smoke opacity[4]. 7.5% water emulsion shows 5% smoke opacity reductionthan that of diesel, where as 2.5% reduction is observed for5% water emulsion at full load.

IV. Conclusions

1. ThevetiaPeruviana biodiesel was prepared in thelaboratory and it was observed that thepropertieswere comparable to that of diesel.
2. Emulsified B20 biodiesel (diesel and 20% biodiesel)with water in the ratios of 5% and 7.5%have beenprepared and utilized as fuels
3. B20 biodiesel showed slightly lesser BTE comparedto diesel due to its lower calorific value.But wateremulsified fuels were found to increase the BTEcompared to that of diesel at fullload.
4. The continuous burning of B20 biodiesel even duringexhaust led to the formation of higherEGT and henceincreased NOx emissions than diesel. But emulsifiedfuels exhibited lowerexhaust gas temperatures andhence reduced NOx emissions. A reduction of 10% inNOxemissions was found for 7.5% water emulsifiedfuel and 8% reduction for 5% wateremulsified fuel.
5. Significant reduction in HC emissions was noted forB20 biodiesel due to its efficientburning than diesel.In the case of emulsified fuels, enhancement of airfuel mixing duringmicro explosion phenomenon inhigher loads improved the combustion processtherebyreducing the HC emissions.
6. The smoke opacity of B20 biodiesel was slightlyhigher than that of diesel due the heaviermolecules ofbiodiesel. Emulsified fuels showed reduction insmoke opacity. This was due tothe faster combustionreaction. 5% reduction in smoke opacity was notedfor 7.5% wateremulsified fuel, and 2.5% reductionfor 5% water emulsified fuel.
7. There is no significant difference in pressure and heatrelease rates for various fuels.

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