© 2017 IJSRST | Volume 3 | Issue 6 | Print ISSN: 2395-6011 | Online ISSN: 2395-602X
Themed Section: Science and Technology

Performance and Emission of Emulsified Fuel in a low Speed Diesel Engine

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ABSTRACT

Effect of water diesel emulsion in a slow speed water cooled four stroke diesel engine is studied. Emulsified fuel in the ratio of 5, 10, and 15 percent of water in diesel is prepared. Tween 80 and Span 80 are used as surfactant with a HLB balance of 8.A mechanical homogeniser is used to produce emulsions at the speed of 3000 rpm for 25 minutes. Experiment is conducted at a constant speed of 780 rpm. A comparative study involving brake specific fuel consumption, brake thermal efficiency, NO_x, CO, HC, CO_2 are recorded for diesel fuel and various emulsions. The results shows significant improvement in engine performance and reduction in emissions using emulsified fuel.

Keywords: Diesel Engine; Water-Diesel Emulsions, Exhaust Emission; Performance.

I. INTRODUCTION

Diesel engines are widely used in engineering machinery, automobile, genset and ships due to economy and part load efficiency. However, conventional CI diesel engines produce high emissions of nitric oxides (NOx), carbon monoxide (CO), carbon dioxide (CO_2), unburned hydrocarbon (HC), smoke and other harmful compounds. As Government is stricting emissions norms tightly, the emissions reduction is a major research objective. Emulsification is the best method to reduce CI engine emissions. Combustion of hydrocarbon witness the reaction of the hydrogen in the fuel and oxygen in the air to produces water in the form of steam. So the water mass produced during combustion can be greater than the mass of the fuel source. So emulsification of the fuel only changes the sequence in which the water is introduced into combustion and water is not introducing as a new compound. Thermodynamic reaction when hydrocarbons are completely burned in the presence of sufficient oxygen is:

$$C_nH_m + (n+m/4)O_2 \rightarrow nCO_2 + m/2 \cdot H_2O$$

In the presence of water at a high temperature, the following steam reforming action and water gas reaction may proceed before the above reaction is initiated.

$$C_nH_m + nH_2O \rightarrow nCO + (m/2+n)\ H_2$$

CO and H_2 may react with O_2 and

$$CO + 1/2\ O_2 \leftrightarrow CO_2$$

$$H_2 + 1/2\ O_2 \leftrightarrow H_2O$$

In the end equilibrium reaction is achieved. Due to the difference in boiling points, water expands or explodes first. Subsequently, the particles of oil are exploded and forced mixing with the air occur enabling complete combustion. So there is reduction of fuel consumption. Ordinarily, NOx is generated when the air is exposed to high temperatures. Water vapor suppressed the reactive region where the NOx is produced. The overall mass increases by adding water which has a higher density increases the momentum and improves the mixture with the air. Many researches focused in using water with fuel as an emulsified fuel

Tsukahara and Yoshimoto [1] observed NOx and smoke reduction with no effect on specific fuel consumption when operating engine on emulsified fuel at low compression ratio of 13.6, 15.6, and 17.0. Ishida M. and Chen Z [2] analyzed experimentally and theoretically the effect of water in the suction air and emulsified fuel on NO formation. Effect of changes in specific heat and the entrained air rate of the burned gas in the combustion chamber showed NOx reduction due to the added water amount of 20% in the emulsified fuel is

almost equal to the one due to an increase of 0.01 kg/kg in the absolute humidity of the suction air. Abu-Zaid [3] investigated the performance of single cylinder water cooled diesel engine using emulsified fuel. Water diesel ratio of 0, 5, 10, 15 and 20 was used. Results indicate addition of water improves engine torque, power and brake thermal efficiency. Park K., Kwak I [4] studied the long term effect of water on motorway-bus diesel engine running on D-13 mode. NOx and PM was reduced simultaneously and specific fuel consumption increased at low speed but decreased at high speed. Armas, O et.al [5] studied the effect of water oil emulsions in indirect injection turbocharger engine and suggest emulsified fuel potential to improve brake thermal effiency and to reduce soot NOx, HC and particulate matter. Anna Lif et al. [6] reviewed the influence of water on the emission and the combustion efficiency. Results showed that there 30% decrease in the emission of nitrogen oxides and up to 60% drop in particulate matters, using up to 15% water in diesel. The combustion efficiency is improved when water is emulsified in diesel. This is consequences of micro explosions, which facilitates atomisation of fuel. Ghojel et al. [7] presented measurements of the performance and NOx and hydrocarbon emissions of a diesel engine operating on a typical diesel oil emulsion and examine through the use of heat release analysis differences found during its combustion relative to standard diesel in the same engine. It is concluded that it produces more thermal efficiency and improved NO_x reductions up to 30%, hydrocarbon emission 60-90%, and peak engine power output is lower and specific fuel consumption is more. Use of the emulsion shown to result in a retarded fuel injection, but for the same engine timing a smaller ignition delay occurs. This results in lower cylinder pressures and temperatures. Nadeem et al. [8] reported that water/diesel emulsified fuel reduces the emissions of NO_x, SO_x, CO and particulate matter (PM) without deteriorating the engine's performance. Emulsion fuels of water and diesel were prepared with different ratio and stabilized by conventional and gemini surfactant, respectively. Experimental results indicate that the emulsions stabilized by gemini surfactant have much finer and better-distributed water droplets as compared to those stabilized by conventional surfactant. It was concluded that huge reduction in NOx, CO, PM and SO_x emission was achieved by the emulsion stabilized by gemini surfactant containing 15% water contents.

Kannan et al. [9] have worked on NO_x and HC emission control using single cylinder engine. The effects of water emulsified diesel fuel combustion on emissions like NO_x and unburnt hydrocarbon and on the brake thermal efficiency, brake specific fuel consumption in a diesel engine were reported. Experiments were conducted on a single cylinder four stroke cycle direct injection diesel engine running at a constant speed with a fuel injection pressure of 200 bars. Tests were done using commercial diesel fuel and emulsified diesel fuel with 10% and 20% water by volume. Fayyad et al. [10] presented an experimental investigation of emulsified fuels as an operating material for vehicle engines. Water is added up to 25% in diesel and benzene separately with addition of 2.5% emulsifier. It is found that brake horse power, engine power and torque have been improved with the emulsified fuel. Omar Badran et al.

used 0, 10, 15, 20, 25 and 30 water/Diesel ratios by volume in a direct injection single cylinder, diesel engine, operating between 1000-1600 rpm. The average increase in the brake thermal efficiency for 30% water emulsion is approximately 5%. The particulate matter and NO_x emissions decrease as the percentage of water in the emulsion increased to 30%. Recently NK Singh [12] presented an experimental result carried out to evaluate performance and exhaust gas emissions of small diesel engine when operated on neat diesel and its emulsions with water. Emulsified diesel fuels of 0, 5, 10, 15 and 20 water/diesel ratio by volume, were used in single cylinder, direct injection diesel engine, operating at 1500-1700 rpm. It was concluded that NO_x, HC, CO, CO_2, black smoke opacity and brake specific fuel consumption, exhaust gas temperature, decrease as the percentage of water in the emulsions increases. In the present work performance and emissions are analysed while running single cylinder slow speed water cooled compression ignition engine on emulsified fuel in the ratio of 0, 5, 10 and 15% volume of water in diesel.

II. Experimentations Details

For preparing emulsion of different compounds having different properties a surfactant or binding substance is needed. In this experiment mixture of Span 80 and Tween 80 are used as surfactant. Mixture is prepared by both surfactants with a HLB balance of 8.

2.1. Experimental apparatus

The test engine in this study is a water-cooled single-cylinder Direct Injection (DI) slow speed diesel engine. Exhaust emissions are measured by an AVL Di-gas analyser, i.e. carbon monoxide, carbon dioxide, hydrocarbon and oxides of nitrogen. The schematic layout of the experimental setup is shown in Figure1. Engine specifications are listed in Table 1.

Table 1 Engine specifications

Type	Four stroke, water cooled, direct injection compression ignition
Number of cylinder	One
Bore × Stroke	114.3*139.7 mm
Compression Ratio	16 : 1
Cubic capacity	661 cc
Rated Power Output	4.4 KW at 1500 rpm
Dynamometer	Rope brake, water cooled

2.2. Test fuels and methods

Three specimens of emulsified fuels were prepared in this study, possessing 5%, 10%, 15% volume of water by weight.

Properties of the test fuels are:

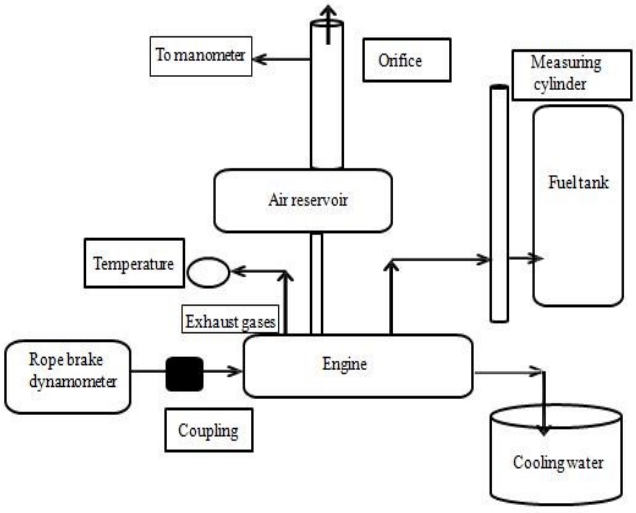

Figure 1. Schematic of diesel engine setup

The baseline diesel fuel has a cetane index of 56. Mechanical Homogenizer is used to make emulsions. Firstly surfactant mixture is prepared with a HLB balance of it is poured into the measured quantity of Diesel. Now mixture of surfactant and diesel is stirred with mechanical homogeniser at a speed of 3000 rpm for 20-25 minutes. Simultaneously required percentage of water is added continuously to make emulsions. The emulsion thus obtained is checked for stability.

The experiments were performed at a constant rated speed of 780 rpm with fixed compression ratio of 16.5: 1. The tests was conducted at 5 kg, 10 kg, 15 kg and 20 kg load and repeated three times for every kind of fuels in order to increase the reliability of test results.

The engine load was controlled mechanically. During the tests, the parameters such as engine power output, fuel consumption, engine exhaust temperature and emissions were recorded.

Figure 2. Slow speed diesel engine test rig

Properties of emulsions	0%w	5%w	10%w	15%w
Density@20°C (Kg/m^3)	830.6	837.5	846.4	853.1
API Density@15°C (Kg/m^3)	832.2	841.1	850	856.7
Kinematic Viscosity@ 40 °C (Cst)	2.724	3.155	3.343	3.632
Specific gravity@20°C	830	839	847.9	854.7
Flash point (°C)	70	86	88	90

Figure 3. Mechanical homogenizer

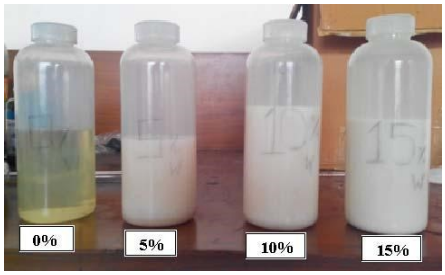

Figure 4. Samples of water diesel emulsions by percentage of water

III. Results and discussion

3.1 Specific fuel consum ption with BHP

Fig ure 5 Show the variation of specific fuel consumption (SFC) o f both the pure dies el and different emu lsions. SFC decrease with engine loads considering the em ulsion (dies el water) as total fue l. It show s that SFC decreases as engine load incr eases, this is due to fa ct that more water wo rks as fuel as more w ater takes space of d iesel in burning proce ss.

The reduct ion in SF C with wat er emulsified diesel may also be attributed to for mation of a finer spray due to rapid evaporation in the w ater, longer ignition d elay resu lts in more fuel bur ning in pre mixed com bustion an d suppress ion of thermal diss ociation due to lower cylinder av erage temp rature.

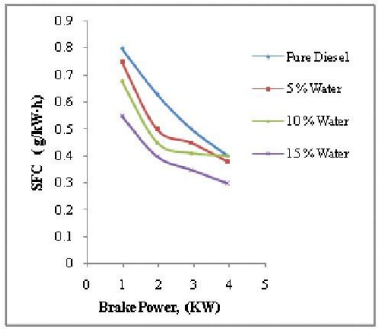

Figure 5. Va riation of S FC with BH P

3.2 Variation of brake the rmal efficiency with BHP

Figure 6 show s the effect of emulsified fuel on the brake thermal efficiency. The maximum increase in the brake thermal efficiency occurs when 15% water in the emulsion is used, and this is due to t he fact that boiling point of water is less than the dies el, so it evaporates first and give birth to micro explosion and secondary atomisation of fuel, subsequently increasing the extra power from combustion of each fuel particle.

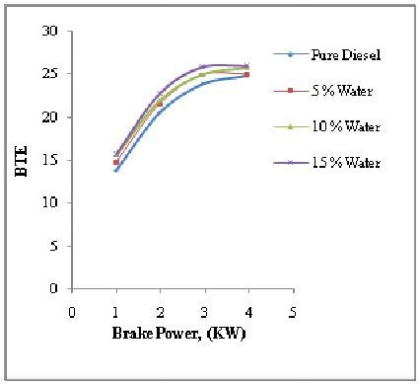

Figure 6. Variation Brake Therma l Efficienc y with BHP

3.3 Variation of NO_x wit h BHP

The variation o f NO_x with engine loa d using em ulsion is s hown in Fig ure7. It is clear that as the p ercentage o f water in emulsion increases, the exha ust temper ature decreases as the heat is absorbed by the a dditional w ater, which subsequ ently decrease the N O_x as it is the produ ct of reacti on of nitro gen with o xygen at higher temperature. The latent heat of water will cool the charge due to the evaporatio n of water, and the cylinder average temperature following injection and before ignition becomes lower as the w ater percentage increase. So red uction of N O_x takes p lace linearly as the percentage of water in crease in the emulsion.

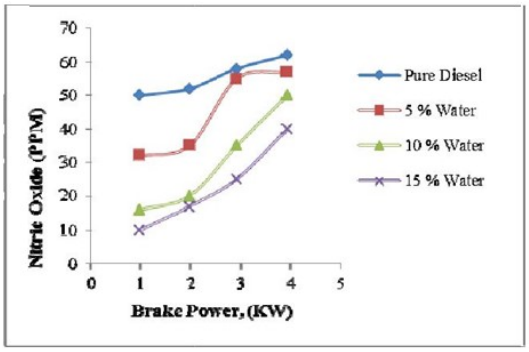

Figure 7. Variation of NO_x with BHP

3.4 Variation of Carbon dioxide with BHP

Carbon dioxide reflects complete combustion of fuel. Combustion of emulsified fuel shows increasing trend with the increase of percentage of water. It gives justification for complete combustion of fuel in case of emulsions compared to pure dies el.

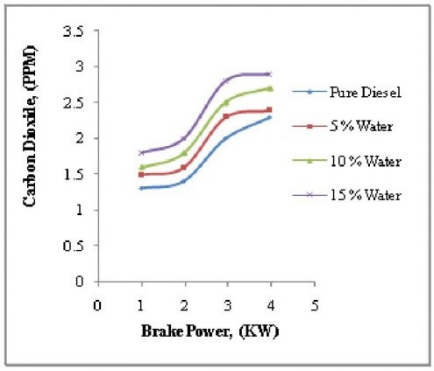

Figure 8. Variation of Carbon dioxide with BHP

3.5 Variation of Carbon monoxide with BHP

Carbon monox ide is a re sult of incomplete co mbustion. It has bee n observed that emission of CO decreases with incr ease in volume of w ater in the emulsion. This happens because water helps in micr o explosion of fuel an d more oxy gen supplied by the added wate r. It is also observed that when t he load is i ncreased C O concentr ation incr eases for al l the samples and pure diesel.

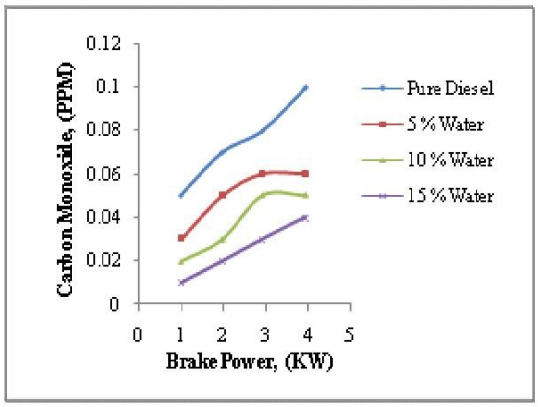

Figure 9. Varia tion of Ca rbon mono xides

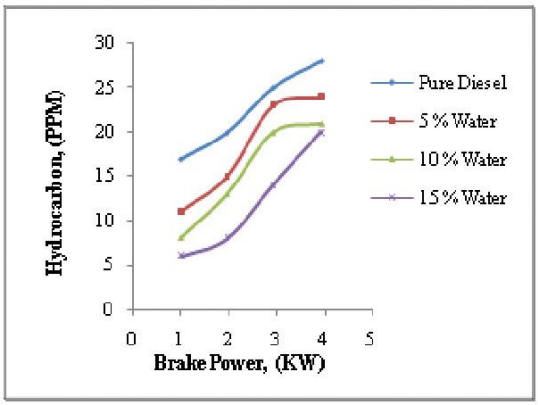

Figure 10. Vari ation of HC with BHP with BHP

3.6 Variation of HC with BHP

HC is produced when fuel move to the exhaust without do ing the work or not getting pro per oxygen for burnin g. In emuls ification of fuel water is added to the fuel, which supplies extra oxygen for proper com bustion of fuel. Figure 10 shows variation of HC wit h load. It shows a decr easing trend of HC while increasi ng emulsio n.

IV. Conclusions

On the basis of the experimental resu lts on slow speed dies el engine u sing emulsified fuels, the follo wing concl usions are drawn:

1) The specific fuel con sumption was observ ed to decrease with increase in the percentage of water in diesel. Results sho w that spe cific fuel consumptio n is decreased by 30% wh en concentration of water is increa sed to15 % .

2) The brake thermal efficiency of emulsified fuel increases with increase in w ater content of emulsion.

3) The NO_x emission is reduced sig nificantly by use of diesel water emulsion. This trend goes on increasi ng with inc rease in amount of water in the em ulsion.

4) Hydrocarb on emissio ns shows d ecreasing trend with emulsion as compared to diesel, how ever when the load i ncreases H C emission s are highe r for emulsified fuel.

5) Carbon mo noxide em issions dec rease with increase in water percentage in the fuel. But not significantly like NO_x and HC. Howe ver carbon dioxide sh ows increasing trend with emulsified.

6) The test results revealed that water up to 15% can be used as a blend fuel with neat diesel fuel in diesel engine with no engine modification. Although there is scope of using higher percentage of water diesel emulsion, but it can be optimized keeping in view the losses of engine.

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