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An Experimental Investigation of Emulsified Fuel in a Slow Speed Diesel Engine for Performance and Emission

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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.

1. 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. [11] 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.

2. 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:

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

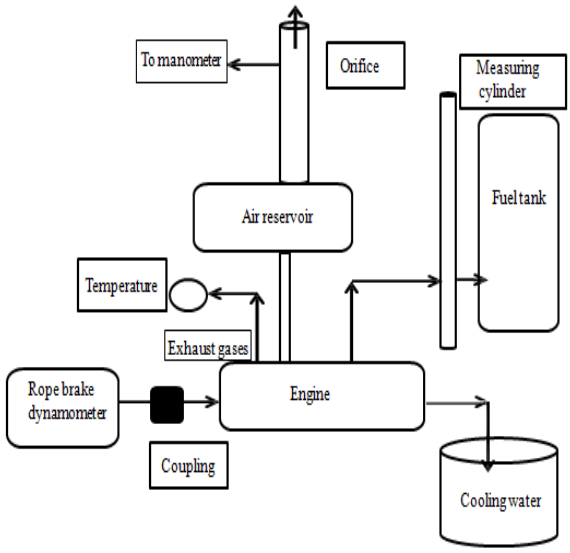

Figure 1 Schematic of diesel engine setup

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 8. 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

Figure 3 Mechanical homogenizer

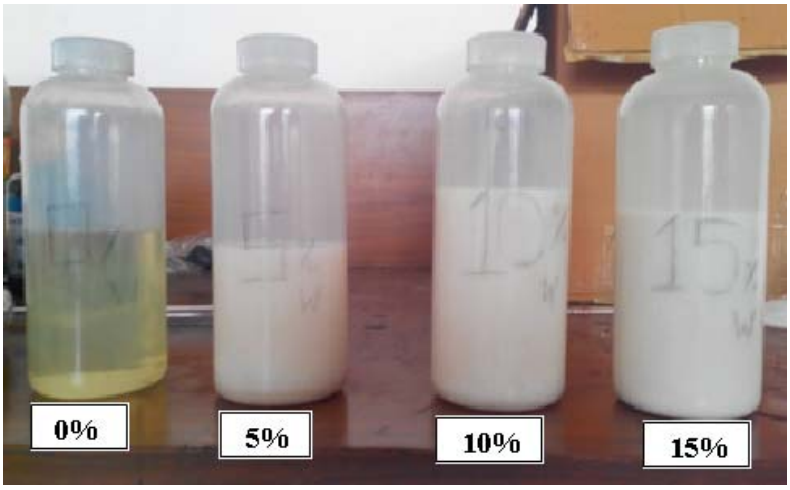

Figure 4 Samples of water diesel emulsions by percentage of water

3. Results and discussion

3.1 Specific fuel consumption with BHP

Figure 5 Show the variation of specific fuel consumption (SFC) of both the pure diesel and different emulsions. SFC decrease with engine loads considering the emulsion (diesel water) as total fuel. It shows that SFC decreases as engine load increases, this is due to fact that more water works as fuel as more water takes space of diesel in burning process.

The reduction in SFC with water emulsified diesel may also be attributed to formation of a finer spray due to rapid evaporation in the water, longer ignition delay results in more fuel burning in premixed combustion and suppression of thermal dissociation due to lower cylinder average temperature.

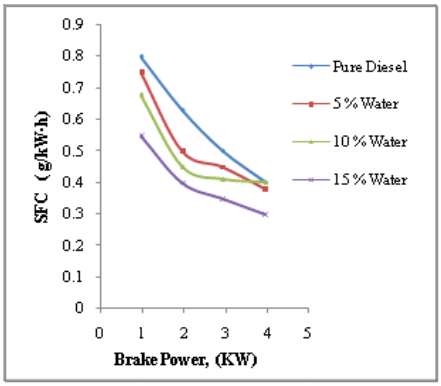

Figure 5 Variation of SFC with BHP

3.2 Variation of brake thermal efficiency with BHP

Figure 6 shows 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 the fact that boiling point of water is less than the diesel, 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.

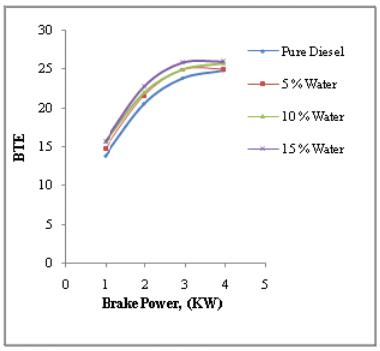

Figure 6 Variation Brake Thermal Efficiency with BHP

3.3 Variation of NO_x with BHP

The variation of NO_x with engine load using emulsion is shown in Figure7. It is clear that as the percentage of water in emulsion increases, the exhaust temperature decreases as the heat is absorbed by the additional water, which subsequently decrease the NO_x as it is the product of reaction of nitrogen with oxygen at higher temperature. The latent heat of water will cool the charge due to the evaporation of water, and the cylinder average temperature following injection and before ignition becomes lower as the water percentage increase. So reduction of NO_x takes place linearly as the percentage of water increase in the emulsion.

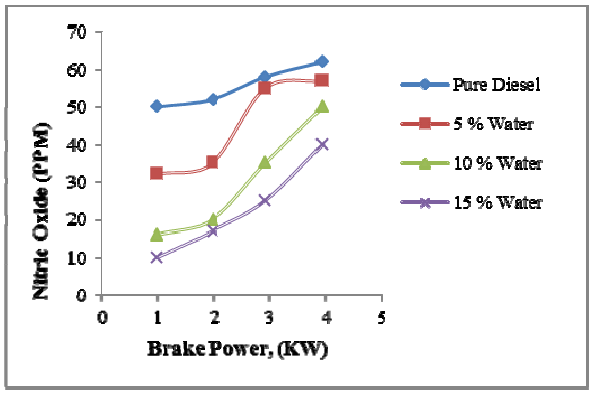

Figure 7 Variation of NO_x with BHP

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 diesel.

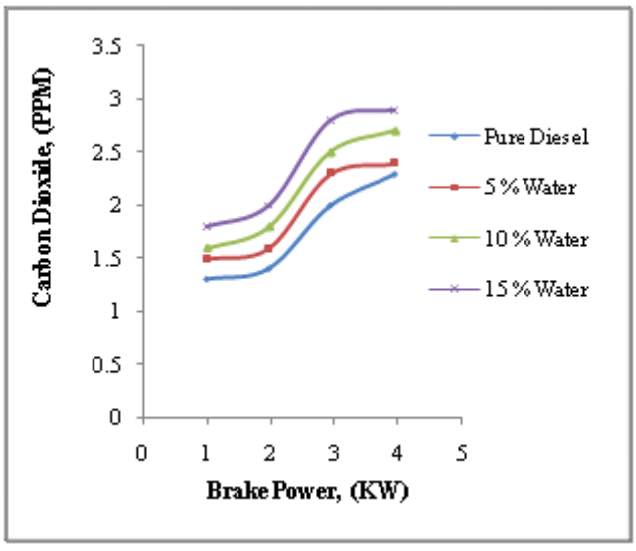

Figure 8 Variation of Carbon dioxide with BHP

3.5 Variation of Carbon monoxide with BHP

Carbon monoxide is a result of incomplete combustion. It has been observed that emission of CO decreases with increase in volume of water in the emulsion. This happens because water helps in micro explosion of fuel and more oxygen supplied by the added water. It is also observed that when the load is increased CO concentration increases for all the samples and pure diesel.

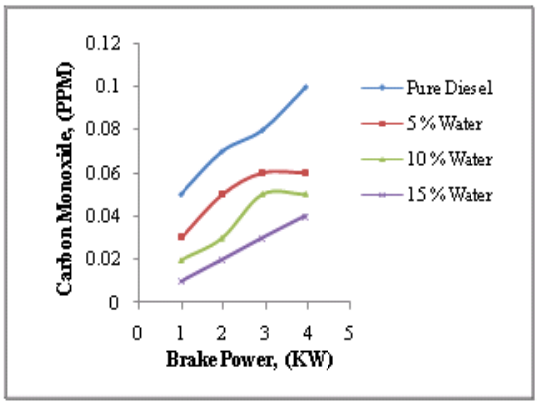

Figure 9 Variation of Carbon monoxides with BHP

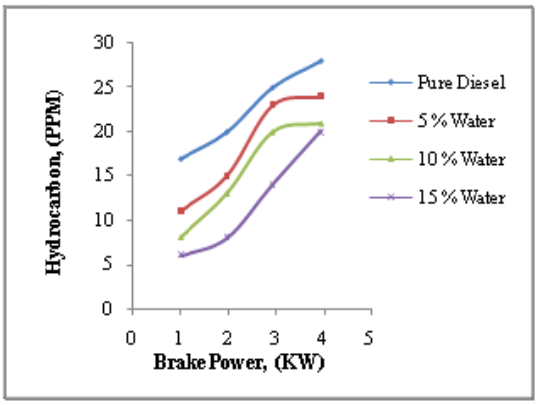

Figure 10 Variation of HC with BHP

3.6 Variation of HC with BHP

HC is produced when fuel move to the exhaust without doing the work or not getting proper oxygen for burning. In emulsification of fuel water is added to the fuel, which supplies extra oxygen for proper combustion of fuel. Figure 10 shows variation of HC with load. It shows a decreasing trend of HC while increasing emulsion.

4. Conclusions

On the basis of the experimental results on slow speed diesel engine using emulsified fuels, the following conclusions are drawn:

1) The specific fuel consumption was observed to decrease with increase in the percentage of water in diesel. Results show that specific fuel consumption is decreased by 30% when concentration of water is increased to15 %.
2) The brake thermal efficiency of emulsified fuel increases with increase in water content of emulsion.
3) The NO_x emission is reduced significantly by use of diesel water emulsion. This trend goes on increasing with increase in amount of water in the emulsion.
4) Hydrocarbon emissions shows decreasing trend with emulsion as compared to diesel, however when the load increases HC emissions are higher for emulsified fuel.
5) Carbon monoxide emissions decrease with increase in water percentage in the fuel. But not significantly like NO_x and HC. However carbon dioxide shows increasing trend with emulsified.

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.

5. References

[1] Tsukahara M and Yoshimoto Y,1992, "Reduction of NOx, Smoke, BSFC, and Maximum Combustion Pressure by Low Compression Ratios in a Diesel Engine Fuelled by Emulsified Fuel," SAE Technical Paper 920464,

[2] Ishida M. and Chen Z.,1994, "An Analysis of the Added Water Effect on NO Formation in D.I. Diesel Engines," SAE Technical Paper 941691,

[3] Abu-Zaid M., 2003, "Performance of single cylinder direct injection diesel engine using water fuel emulsions," Energy Conversion and Management, 45, pp.697-705.

[4] Park, K., Kwak, I., 2004, "The Effect of water emulsified fuel on a motorway-bus diesel engine. KSME International Journal, 18 (11), pp.2049-2057.

[5] Armas, O., Ballesteros, R., Martos, F.J., Agudelo, J.R., 2005, "Characterization of light duty diesel engine pollutant emissions using water-emulsified fuel," Fuel, 84, pp.1011-1018.

[6] Anna Lif, Krister Holmberg, 2006, "Water in diesel emulsions and related systems, Advances in Colloid and Interface Science, 123-126, pp.231-239.

[7] Ghojel J, Honnery D, and Khaleefi Al K.,2006, "Performance emissions and heat release characteristics of direct injection diesel engine operating on diesel oil emulsion," Applied Thermal Engineering, 26, pp. 2132–2141.

[8] Nadeem M. , Rangkuti C, Anuar K. , Haq M.R.U. and Tan,Shah I B, 2006, "Diesel engine performance and emission evaluation using emulsified fuels stabilized by conventional and gemini surfactants," Fuel, 85 pp.2111–2119,.

[9] Kannan K. and Udaya kumar M., 2009, "NOx and HC emission control using single cylinder engine," ARPN Journal of Engineering and Applied Sciences, pp.4.

[10] Sayel M. Fayyad., 2010, "Experimental Emulsified Diesel and Benzen Investigation," Research Journal of Applied Sciences, Engineering and Technology, 2 (3) pp. 268-273.

[11] Omar Badrana, Sadeq Emeishb, Mahmoud Abu-Zaidc, Tayseer Abu-Rahmaa, Mohammad Al-Hasana, Mumin Al-Ragheba,2011, "Impact of Emulsified water/diesel mixture on engine performance and environment," International journal of thermal and environment engineering, pp.3.

[12] NK Singh, 2012, "Experimental investigation of diesel emulsions as fuel in small direct injection compression ignition engines," MIT International Journal of Mechanical Engineering, 2, pp. 39-44.