Performance and Emission Characteristics of a Single Cylinder Four Stroke Diesel Engine with Water-Diesel Emulsions

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Abstract— The current trends in CI engine are to use Water-diesel emulsion as alternative fuel. It can be employed directly to the existing CI Engine system with no additional modifications. This system helps in reduction of NOx as well as PM, which in turn improve the combustion efficiency of the engine. However there are still investigations have to be done. The current work mainly concentrated on diesel engine run on water-diesel emulsions and its effect on engine performance and emissions were studied. The various loads were applied on a constant speed diesel engine run on water-diesel emulsions of varying ratios of 0.2:1, 0.3:1. 0.4:1 and 0.5:1. Emission and performance characteristics were measured and were compared with base diesel operation. The emissions like NOx and smoke density were found to decrease greatly and brake thermal efficiency was found to increase at high loads. Smoke level was 4.2 BSU and 3 BSU for base diesel and water diesel emulsion of 0.4. The ignition delay was found to increase with water diesel emulsions. This also increased the maximum rate of pressure rise and peak pressure. The engine was found to run rough with water-diesel emulsions. The optimal water-diesel ratio was found to be 0.4:1 by weight. HC and CO emissions were found to increase with water diesel emulsions.

Key words: Water Diesel Emulsion, NOx, Surfactant

I. INTRODUCTION

Diesel Engines are used in a wide range of applications due to fact that they have high reliability and fuel economy. Currently in several fields like decentralized power generation, mass transportation etc. there is no viable alternative to the diesel engine. It is also well known fact that passenger car segment now a days also find application of Diesel engines. CO2 emissions are low (about 30%) in diesel engines compared to that of gasoline engines [1]. However, the main drawbacks of diesel engines are smoke emissions and high NOx.

The formation of NOX occurs in the combustion chamber at high temperatures when oxygen and nitrogen are present. The main reason for smoke emission is due to heterogeneous air fuel mixture formation in diesel engines. Many techniques were implemented such as shaping of injection rate, retarding the injection timing, split injection, modifications in charge composition, charge air chilling, recirculation of exhaust gas, modification of the combustion chamber geometry for the improvement of air motion etc. in order to reduce the emissions. Normally, in diesel engines it is observed that there is a significant increase in particulate emissions and smoke when tried to reduce NOx using different techniques and vice versa [2]. Thus, automobile engineers are still facing a challenge in reducing particulates and NOx simultaneously without affecting fuel economy.

NOx emission can be reduced by lowering the charge temperature using water. There are many techniques to introduce water into engine cylinder like direct injection, using water diesel emulsions, fumigation etc. Fumigation is a simple method but twice the water quantity is required as compared to the use of water diesel emulsions to obtain an equal effect on emission reduction [3]. Two injectors are used in the case of water injection, one for diesel and the other for water. New research has led to new injection technique in which a specialized injector is used to inject both diesel and water with a single apparatus [4].

Simultaneous reduction in particulates and NOx with improvement in fuel economy can be obtained using water diesel emulsion. A conventional injector is used to inject the emulsion directly into the engine cylinder. NOx emission can be reduced by lowering the charge temperature using water diesel emulsion. NOx can also be reduced by Chemical effects [5&6]. Due to the chemical effect [11] and micro explosion [7, 8, 9, 10] of water there is a reduction in smoke. Brake thermal efficiency of the engine is improved. Water diesel emulsions have shown increase in ignition delay and HC levels [10, 12, 13, and 14]. Water to diesel ratios between 0.4 and 0.5:1 by weight have been suggested based on viscosity, starting performance and emulsion stability [10&15].

Tadashi Murayama et al [10] have tested different water diesel emulsions (up to 0.8:1 water to diesel ratio) at a fixed output and under different injection timings. The effect of load at fixed water to diesel ratio of 0.8:1were also investigated. A significant rise in HC levels and reduction in NOx and smoke were observed. At high loads there was an improvement in specific fuel consumption. There was an increase in the ignition delay and peak pressure. CO levels decreased at high loads and increased at low loads.

At full load conditions, 50% reduction in NOx & smoke emissions was achieved and 1 to 2% of fuel savings was obtained by using W/D emulsions. Water up to 30% by volume was used to analyze the performance and emissions (NOx, CO etc) parameters at different injection timings. Tests were conducted at water to diesel ratio of 0.5:1 at the rated load. Various parameters were varied such as injection timing, injection rate and nozzle opening pressure and found a decrease in NOx and SFC at certain conditions. Thus it is clear that using the water diesel emulsion has a great influence on decreasing NOx level.

II. EXPERIMENTAL SETUP

Present work is on a single cylinder diesel engine was mounted and connected with a dynamometer of water cooled eddy current type. Emulsions of water and diesel of 30%, 40% and 50% on volume basis were prepared. Tests for the given set up were carried on under various load conditions and various performance characteristics, emissions (NOx, HC) were obtained and compared with pure diesel under operation.

The engine was coupled to dynamometer of water cooled eddy current type. Fuel flow rate was obtained using an electronic balance type which operates under gravimetric basis. Air flow rate was obtained by calculating the air pressure and intake air temperature using sensors. An exhaust gas analyzer was used to measure HC and CO levels in the exhaust. The NOx emission was obtained by using an analyzer which works on the principle chemiluminescence. Smoke levels were obtained by using a standard Bosch smoke measuring apparatus. Signals were recorded and analyzed on a personal computer based data acquisition (DAQ) system. DAQ which provides the reacquired data's such as power, torque, speed and exhaust temperature. The specifications of the test engine rig have given below.

Type of Engine	4-stroke, aircooled, single cylinder DI Diesel Engine
Bore X Stroke	87.5X 110 mm
Injection timing	22.8 bTDC (static)
Compression ratio	17.5:1
Rated power	4.42 kW at 1500 rpm

Table 1: Specifications of Test Engine

Water-diesel emulsion was formed by using a surfactant with a Hydrophile Lipophile Balance (HLB7). The various stabilities were obtained by varying the Surfactant quantity, speed and amount of water added. Here for 1% by weight was used and the stability time was about one and half days which were stirred at about 15000 rpm with a mechanical stirrer. A good emulsion was prepared for a proper operation of engine else failure of the injector and other engine parts takes place. The emulsion was injected into engine using the standard injection system.

III. RESULTS AND DISCUSSION

A. Performance Characteristics:

Brake thermal efficiency is plotted against brake power in Fig. 1. With water diesel emulsions break thermal efficiency increases at high loads. The increased air content in the spray and micro explosion is probably the reason for the increase in brake thermal efficiency. Brake thermal efficiency could also be improved due to the increased ignition delay which gives rise to greater rate of combustion. The charge becomes overcooled at low loads, thereby reducing brake thermal efficiency at low loads.

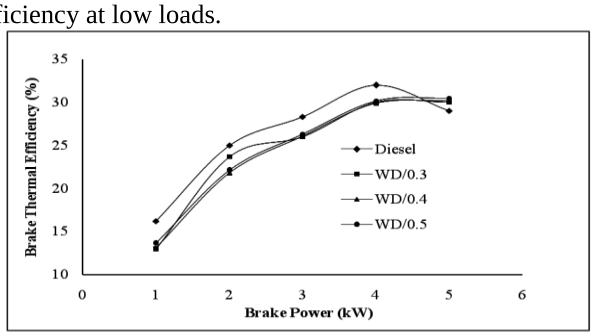

Fig. 1: Brake Thermal efficiency Vs Brake power.

The brake thermal efficiency was found to be maximum at water to diesel ratio of 0.4:1.The brake thermal efficiency of base diesel engine was always greater than that with water diesel emulsions. The maximum brake thermal efficiency with water-diesel emulsion of 0.4 was found to be 31 while it was 34 for base diesel. From Fig. 2, it is clearly evident that HC emissions increase at all loads. Introduction of water reduces the temperature in the cylinder. This can cause poor combustion and this could be the reason why HC emissions increase with water diesel emulsions.

B. Emission Characteristics:

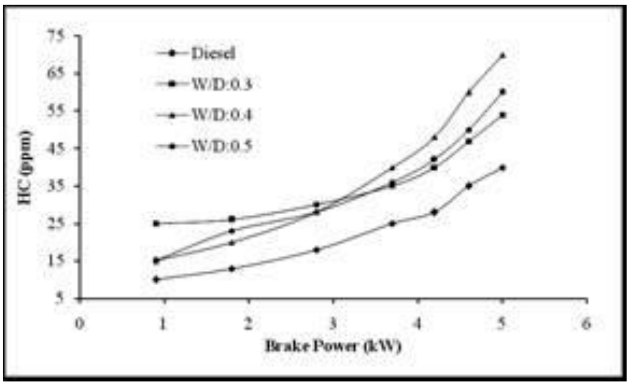

Fig. 2: HC vs Brake power.

Introducing water into diesel causes incomplete combustion, particularly at low loads. This could be the reason why CO levels increase at low loads. At high loads, CO levels of both base diesel and diesel emulsion are almost the same.

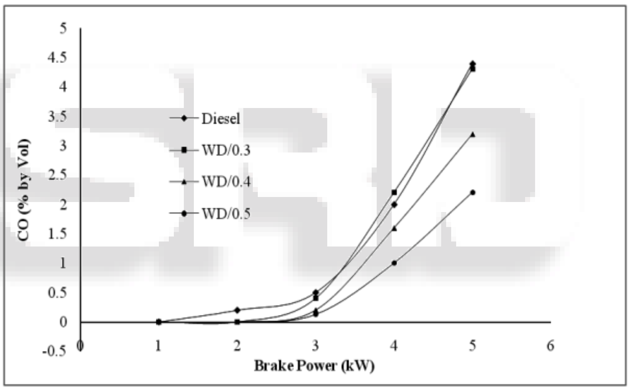

Fig. 3: CO vs Brake power

Fig. 4 shows variation of NOx with brake power. For base diesel NOx was 703ppm while it was 492ppm for water to diesel ratio of 0.5 at 5kW. Introducing water into the engine lowers the in-cylinder temperature. This hinders Nitrogen and Oxygen radicals from combining to form NOx. Smoke density was found to decrease at all loads as the water content increases. This could be due to the increase in hydroxyl ions and also due to the phenomenon of micro explosions.

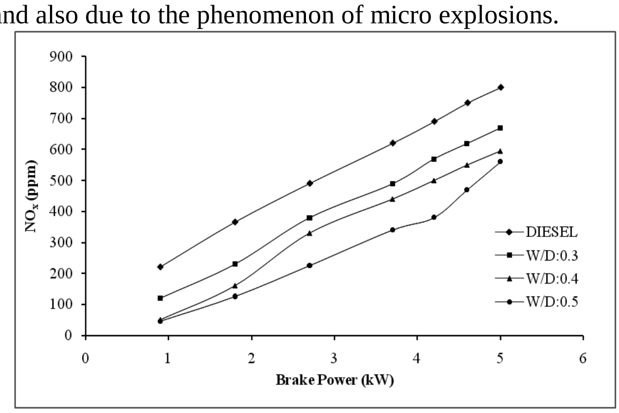

Fig. 4: NOx vs Brake power

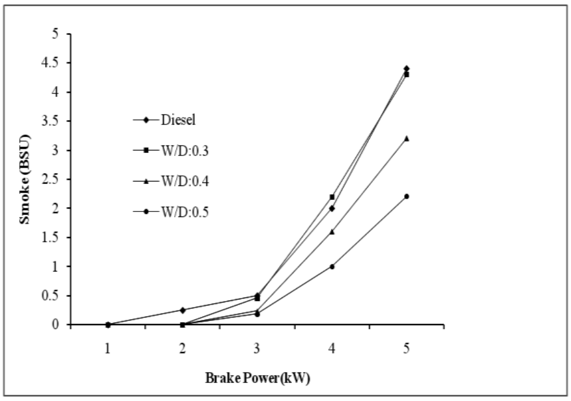

Fig. 5: Smoke vs Brake power.

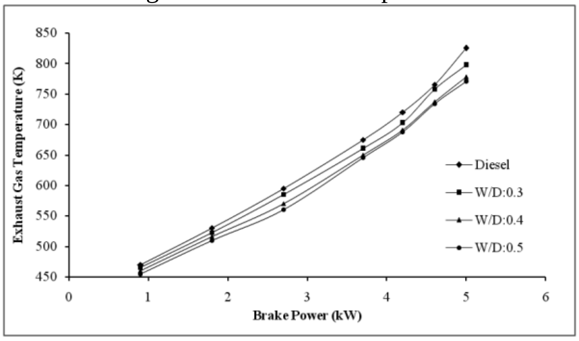

Fig. 6: Exhaust Gas Temperature vs Brake power.

IV. Conclusions

The significant conclusions based on experiments conducted using W/D emulsions are presented below:

- Use of the water diesel emulsion:
- Drastically decreases smoke and NO level at all loads.
- Increases peak pressure at high loads and decreases it at low loads.
- Rises the heat release rate in the premixed burn phase significantly. There is a reduction in the temperature of the gases in the cylinder during the expansion stroke.
- Increases CO levels at low loads and decreases it at high loads.
- Increases ignition delay & maximum rate of pressure rise.
- Increases the brake thermal efficiency at high loads. However, the brake thermal efficiency drops in the lower load range.Rises HC levels at all loads till a water to diesel ratio of 0.4:1At 4.7 kW and 0.5:1 water to diesel ratio:
- Smoke density decreases from 3.7 BSU to 1.9 BSU.
- Brake thermal efficiency rises from 31.3% to 32.7%.
- NO level decreases from 752 ppm to 463 ppm. As compared to neat diesel operation.

Thus, it is concluded that significant reduction in smoke emissions & NOx can be obtained also improvements in performance of a diesel engine can be observed by using water diesel emulsion. Adverse effects on CO, HC levels and engine roughness is observed.

A. Nomenclature:

PM	Particulate matter
HLB	Hydrophile Lipophile Balance
CO	Carbon monoxide
BSU	Bosch smoke unit
Rpm	Revolution per minute
NOx	Oxides of nitrogen
HC	Hydro carbon
TDC	Top dead center
CO2	Carbon di oxide
NO	Nitrogen oxide
bTDC	Before Top dead centre

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