ISSN 2229-5518

Water-in-Diesel Emulsion – An Eco-Friendly Fuel for Stationary Diesel Engines

R. K. Swain, Sunita Panda

Abstract: The primary object of the present investigation is to evaluate the performance characteristics of a small-utility stationary diesel engine adopting water in diesel emulsion for carrying out the ex-periments, the emulsion was used in a four stroke single cylinder direct injection diesel en-gine and was obtained with the aid of a mechanical mixer. A large reduction of NOX concentration was obtained by using different concentration of water in fuel emulsion. Furthermore improve-ment of fuel economy and reduction of exhaust smoke were obtained.

Keywords: *Break Thermal Efficiency, Break Specific Fuel Consumption, Diesel Water Emulsion,* NO_X *Emission, Particulate Matter, Smoke Density*

Introduction

The world, at present is caught on the horns of twin problems energy (fuel) crisis and environmental degradation. Internal Combustion (I.C.) engines which are proven to be indispen-sable to our transportation and agricultural sector have fallen on victim to these problems. Due to the higher fuel efficiency, higher Compression Ratio (CR) and simplicity in design diesel en-gines are becoming popular and are being used in day to day life during the past decade. The higher fuel efficiency in the diesel engine is achieved due to the high compression ratios along with relatively high oxygen concentration in the combustion chamber. However, these same factors results in high NO_X emission in diesel engine. The stringent emission norms have been an important driving force to develop the internal combustion engines more environment friendly. The main pollutants from diesel engines are NO_X, and particulate matter (PM). The mechanism of formation of NO_X and particulate matter in the combustion chamber of diesel engines are con-tradictory and the simultaneous reduction of both is very difficult [1]. Researchers have attempted to reduce the emission and improve the fuel conversion efficiency of diesel engines. It is also seen that the fuel consumption decreases with the use of emulsified fuel due to which com-plete combustion of fuel takes place thus reducing the CO_2 emission also. One promising method may be the use of water emulsified diesel which can economically accomplish the above goals. An emulsion has a heterogeneous system consisting of at least one immiscible liquid intimately dispersed in another in the form of droplets, whose diameter in general, exceed 0.1 micron. The stability of the system is accentuated by additives called surfactants. The dispersion phase of a liquid, in which another liquid is mixed in the form of droplets, is called the continuous phase or external phase. The phase which is dispersed is known as disperse one internal phase. When the continuous phase is aqueous the emulsion is called oil-in-water (O/W) type of emulsion. On the other hand when the continuation phase is an oily phase, the emulsion is called water-in-oil (W/O) type of emulsion. In the water emulsified diesel, the droplet size of the emulsion fuel is one of the most important factors determining the subsequent combustion characteristics [2]. The use of water in fuel emulsion has significantly been given by the phenomenon of "Micro-explosion" which was first reported by IVANOV and N EFEDOV [3]. Further Hsu [4] reported that smoke and NO_X emissions decrease as the water amount in emulsion is increased and the maximum pressure did not change significantly at all load conditions of investigation. Lif and Holmberg [5] reviewed the influence of water on the emissions and on the combustion efficiency which is improved when water is emulsified with diesel. An experimental investigation was var-ied out by to produce a stable diesel water emulsion fuel by Bardan *et al.* [6] under different op-erating condition and its effect on engune performance and emission was studied. Abdulaziz H.EI. sinawi[7] in his work provide a provides a better understanding of the effects of the exis-tence of water in fuel in the form of emulsion on spray combustion and pollutant emissions namely NO_X and carbon monoxide. Diesel-water emulsion, as alternative fuel, has potential to significantly reduce the formation of NO_X and smoke in the diesel engine [8].

Preparation of Emulsion

The technique adopted for the preparation of emulsion is based on the mayonnaise method for emulsion.

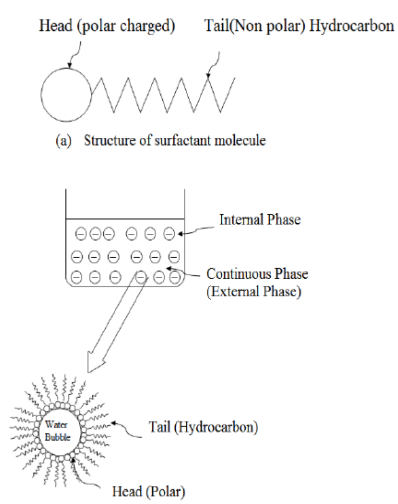

Figure 1 - Microscopic view of surfactant molecules in the water in oil (W/O) emulsion

In this

technique, the surfactant is dissolved in the continuous phase and the liquid to the emulsi-fied is added, with stirring frequently. This addition is made gradually in a batch wise fashion and the emulsion first obtained is passed through a high agitation device.

The preparation of the emulsion may be regarded as taking place in two stages.

Stage 1 Involves the actual manipulation of materials

Stage 2 Involves the actual mixing step and the equipment used in emulsion.

In the former stage the surfactant is added to the continuous phase with constant hand stirring. After the surfactant is dissolved completely. Water is added in phase wise followed by constant stirring. In the latter state the above prepared mixture is passed through a mechanical system to provide required level of agitation for the formation of emulsion.

Experimentation

In order to evaluate the potential of water-in-diesel operated compression ignition engine, a comprehensive experimental investigation were carried out on a single cylinder four stroke direct-injection diesel engine.

Engine Specification

Single Cylinder 4-S Kirloscar TAF-1 Diesel Engine

Bore	87.5 mm
Stroke	110 mm
Cubic capacity	661.7 mm^3
Length	531 mm
Width	546 mm
Height	356 mm
Weight	165 kg
Rated Speed	1500 rpm
Maximum Speed	2000 rpm
Minimum Speed	1200 rpm
Min. Idling Speed	750 rpm
Nozzle Pr.	200 kg/cm^2

The test set up and the necessary instrumentation for study of the water-in-diesel emulsi-fied fuel operated diesel engine are depicted in the block diagram as below. The engine was first operated on neat diesel fuel at a constant RPM to generate the base line data for comparison with the results obtained by using emulsified fuels of different concentrations at the same operating conditions.

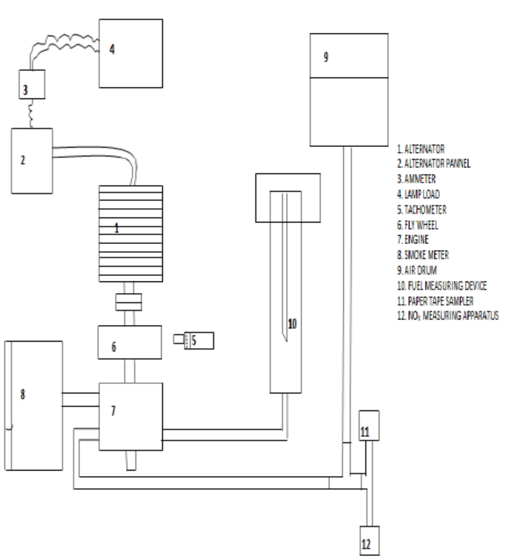

Figure 2 - Schematic diagram of Experimental Set up

Emulsification Techniques

a) Selection of emulsifying agent

A mixture of two emulsifying agents in a definite proportion has been selected for the experi-ment. One of the emulsifying agent was Sorbitan Monostearate (SPAN-60) soluble in diesel and other was polyoxyethylene sorbitan monostearate (TWEEN-60), soluble in water.

b) Preparation of emulsion

The emulsion was prepared and the operation was carried out in two stages.

Stage 1 –

A little amount of diesel oil was taken in a test jar and total amount of emulsifying agent was added to that and was shaken until a major part of the surfactant got dissolved in the con-tinuous phase. The total amount of water was added into the test jar by one to five millimetre every time followed by a vigorous stirring.

Stage 2 –

Then the above mixture was passed through a mechanical system (line diagram shown in figure below) for several times to provide required amount of agitations needed for the formation of emulsion. This involves the actual mixing.

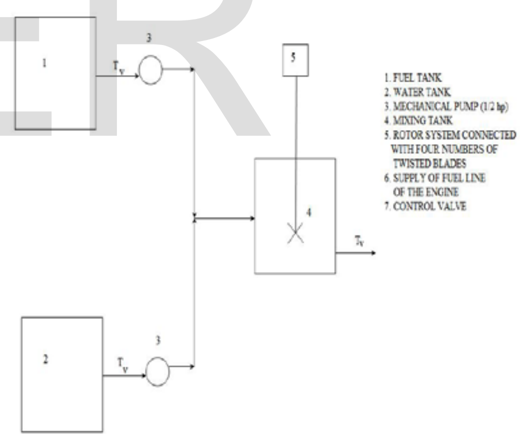

Figure 3 - Schematic Diagram of the Emulsifying Equipment

Methodology

First of all the blends of 5%, 10%, 15% and 20% of water with diesel were prepared. To find out the present condition of the engine a constant speed test with diesel as a fuel was carried out and the base line data were generated. The performance tests on the engine with various blends of water-in-fuel emulsion were preformed. various performance and emission parameters such as fuel rate, air consumption, smoke level, particulate matter, NOX concentration and load in terms of electric power were recorded. The engine was started at no load by pressing the inlet valve with decompression lever and released suddenly when the engine was hand cranked. Then the speed control system was adjusted to set the engine at rated + 2% speed and was allowed to run till

ISSN 2229-5518

the steady state conditions were obtained. The rate of fuel consumption was measured with the fluid flow meter and a stop watch was used to record the time period for the con-sump-tion of 100 cc of diesel. The engine was loaded gradually keeping the speed constant at 1500 rpm and afterwards with emulsified fuel of varying water to diesel ratio.

Results and Discussion

As described in the last chapter extensive experimental investigations have been carried out on a single cylinder four stroke diesel. The engine was run on pure diesel with variable load and at a constant speed (i.e. rated speed). The engine was also run at the same rated speed with different water-in-diesel emulsified fuel.

The experimental results so obtained have been plotted to evaluate the relative engine performance and its emission characteristics.

Engine Performance

Figure 4 shows the variation of BSFC with BMEP. It is evident from this figure that the BSFC decreases with BMEP for both neat and emulsified fuels. The reasons for such a trend of variation can be that when power output increases the value of BSFC decreases and becomes minimum at a point where the equivalence ratio has a very low value. The leaning of the mixture beyond stoichiometric increases thermal efficiency till maximum. Hence minimum fuel con-sumption is attained at leaner mixture. This is because of the fact that heat transfer losses are less with lean mixtures and the availability of more air ensures complete combustion.

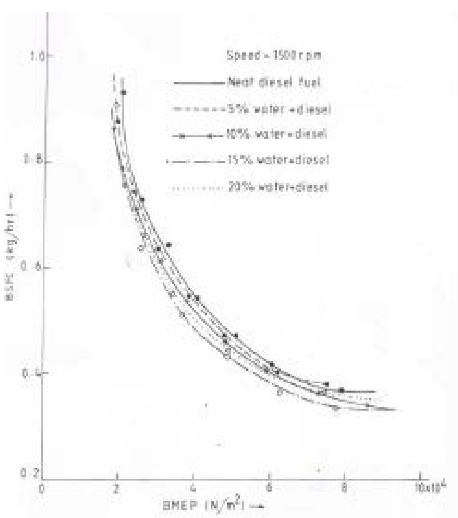

Figure 4- BSFC as a function of BMEP for various water-to-diesel ratio in emulsified fuel.

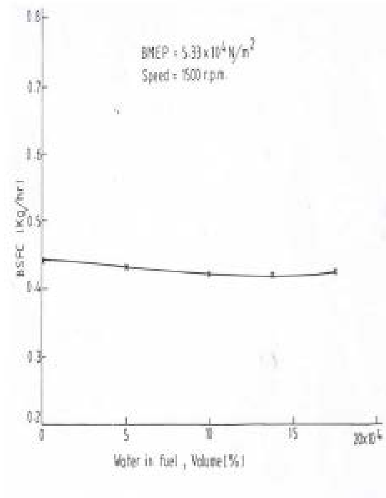

Figure 5- BSFC as a function of water to diesel ratio for emulsified diesel engine.

It is also found from figure 5 that the value of BSFC decreases as the water to diesel fuel ratio increases in an emulsified fuel. It can be seen that in the heavy load significant decrease of specific fuel consumption occurs. In the light load range only a slight increase of BSFC resulted from the use of emulsified fuel. It has also observed that the optimum value for water to diesel fuel ratio between fifteen to twenty percent by volume. This may be due to the delay of ignition with increased water. Another reason that may be attributed in the effects of dilution of charge below the optimal value for which the flame velocity reduces. Secondary atomisation due to rapid volumetric expansion of the water particles in the water-in-oil type emulsion, a micro ex-plosion effect.

Figure 6 and 7 below show the variation of brake thermal efficiency with BMEP and wa-ter to diesel fuel ratio respectively. The brake thermal efficiency gradually increases as power output increases. The brake thermal efficiency increases as the leanness of the mixture increases. The leaning of the mixture beyond stoichiometric increases the thermal efficiency till maximum.

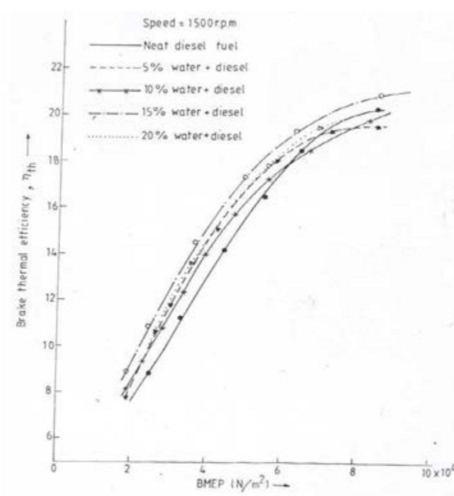

Figure 6 - Brake Thermal efficiency as a function of BMEP for various water-to-diesel ratio in emulsified fuel.

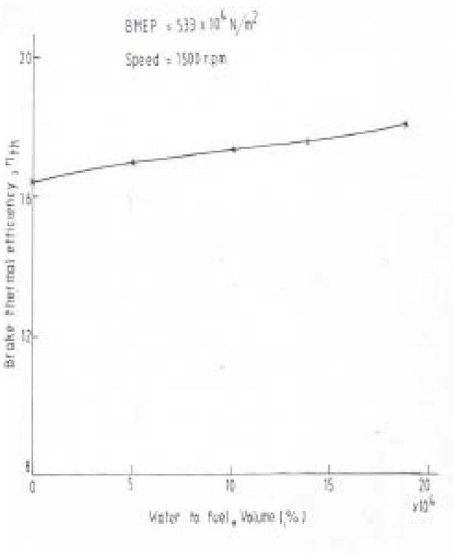

Figure 7- Brake thermal efficiency as a function of water to diesel ratio.

The combustion efficiency increases with water content since, although the input air/fuel mixture was lean, more intimate mixing was achieved and the reaction approached closure to completion at a higher temperature level.

Engine Emission

The figure 8 and 9 demonstrate the nature of variation of smoke density and water to die-sel fuel is evident in the figures. The value of smoke density increases with the increasing of load. This effect may be due to the improper mixing at fuel rich region and raising of combustion temperature. The smoke density also observed to be decreasing with increase in water to diesel ratio. This may be due to the fact that when emulsified fuel is used the concentration of water increases in the fuel rich region between the flame and the surface of the droplets. The decrease of combustion temperature and also the improved mixing due to the water explosion reduces the smoke formation especially in gas phase.

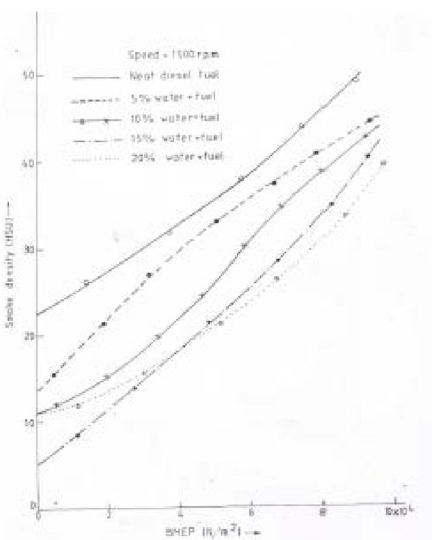

Figure 8- Smoke density as a function of BMEP in emulsified diesel engine.

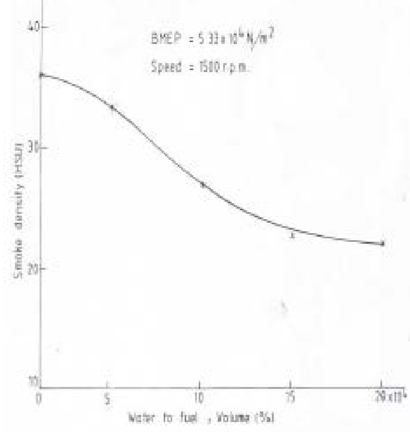

Figure 9- Smoke density as a function of water to diesel ratio.

The figures 10 and 11 shows the variation of NOX concentration with increasing of load and increasing of water to fuel ratio in the emulsified fuel respectively. The reduction of NOX concentration was more significant with the increase of water to diesel fuel ratio in the emulsi-fied fuel.

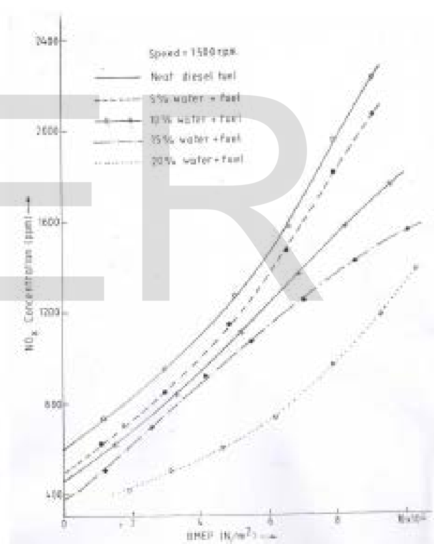

Figure 10- NO_x concentration as a function of BMEP.

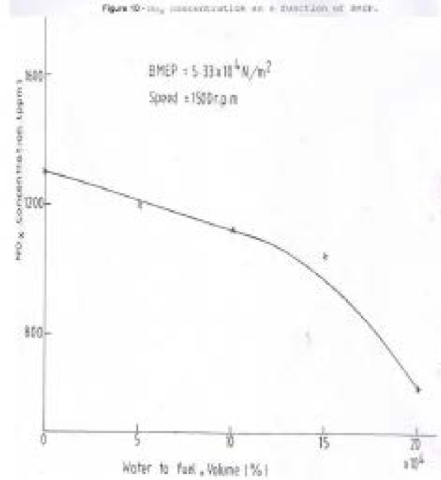

Figure 11- The concentration of NO_x as a function of water to diesel ratio.

ISSN 2229-5518

The reasons of such behaviour can be explained that as when diffusional burning around individ-ual droplets takes place, the chemical activities at the flame area expected to be dimin-ished due to the reduced chemical head released at the flame for unit mass of liquid vaporized. It is well known that high flame temperature diffusional burning is a major source of NOX production, hence reductions in the chemical activities result in significant reductions in NOX production. More over when water was introduced into the combustion cham-ber at the end of suction or compression stroke, the gas tem-perature at the end of compression and combustion gas de-creases. The decreased combustion temperature and in-creased water vapour at the fuel rich re-gion between the flame and the surface of the fuel droplet prove effective in bringing down the level of NOX.

Conclusion

From the experimental result reported here, it is concluded that use of water emulsified diesel fuel has a potential to im-prove the performance and emission characteristics of diesel en-gine. More emphasis should be given on the practical im-plementation of the emulsified fuel. The result of the present investigation may be summarised as given below

1) Marked improvement in specific fuel consumption is observed with an optimum value of 15% water.

2) The diesel engine using emulsified fuel have thermal efficiency is slightly better in compara-tive with the use of neat diesel oil.

3) The reduction of emission parameters such as NOX and smoke density advocate strongly in favour of emulsified fuel for application in small utility diesel engines.

Reference

[1] J. Ghojel, D. Honnery, and K. Al-Khaleefi, “Per formance, emission and heat release charac-teristics of direct injection diesel engine operat-ing on diesel oil emulsion”, Applied Thermal En-gineering, vol. 26, pp. 2132-2141, 2006.

[2] J. W. Park, K.Y. Huh, and K.H. Park, “Experimen tal study on the combustion characteristics of emulsified diesel in a rapid compression and expansion machine”, Proc. Instn. Mech. Engrs. Vol. 214, pp. 579-585, 2000.

[3] V. M. Ivanov, and P. I. Nefedov, “Experimental investigation of the combustion process of natural and emulsified fuels”, (Russian) 1962, NASA Tech. Translation TTE-258, January 1965.

[4] B. D. Hsu, “Combustion of water-in-diesel emuls ion in an experi-ment medium speed diesel engine”, SAE, pp. 2285-2295.

[5] A. Lif, and K. Holmberg, “Water-in-diesel emuls ions and related systems”, Advances in Col-loid and Interface Science, vol. 123-126, pp.

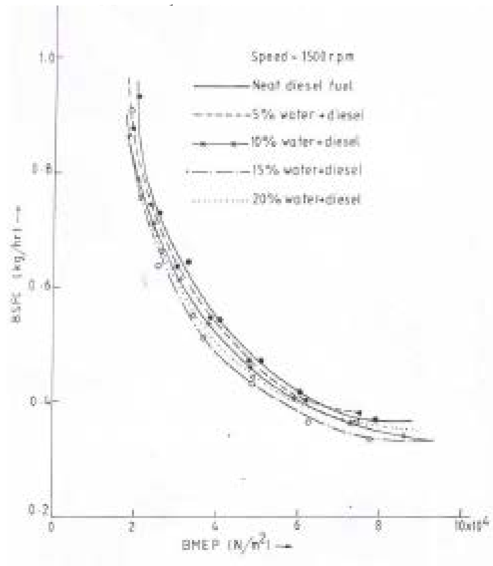

Figure 4: BSFC as a function of BMEP for various water-to-diesel ratio in emulsified fuel.

sel mixture on en
& Environmental
ative Fuel To Re-
es, Technologies,
f experience in
of publications
nd Renewable
ences of inter-
n teaching and