

# Ferrodiesel

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**Abstract**— Ferrofluid -diesel blend (Ferrodiesel) are fuels for regular diesel engines. The advantages of ferrofluid diesel blend are reductions in the emissions of nitrogen oxides and particulate matters, which are both health hazardous, and reduction in fuel consumption due to better burning efficiency. An important aspect is that ferrodiesel can be used without engine modifications. This paper presents the influence of ferrofluid on the emissions and on the combustion efficiency. Whereas there is a decrease in emissions of nitrogen oxides and particulate matters, there is an increase in the emissions of hydrocarbons and carbon monoxide with increasing ferrofluid content of the blend. The combustion efficiency is slightly improved when ferrofluid is blended with diesel.

**Index Terms**— Ferrofluid-diesel blend, ferrofluid, nitrogen oxide emission, engine performance.

## I. INTRODUCTION

From the beginning of engine development there has been researches going to purge the emissions as far as possible. There have been many techniques. As combustion itself being a difficult phenomenon, even to scratch its surface would require profound knowledge not only in thermodynamics, but also in fluid mechanics too. Still that won't be enough for travelling such a feet. The main aim of this paper is that to give equitable information in the reduction of formation of  $\text{NO}_x$  by reducing the temperature inside the chamber. Combustion being an exothermic reaction it will be impossible for ceasing the formation of  $\text{NO}_x$  instead this focuses on a reduction in its formation. For reconnaissance, a combined study of ferrofluid and combustion was performed.

The earlier studies have shown that emulsified fuels and nano particles promote fuel combustion. In this study, an oil-based ferrofluid is added to diesel fuel to explore the effects on engine performance and exhaust emissions of a diesel engine. Using oil-based ferrofluid has advantages compared to other nano powders. It can be diluted and can therefore reap the benefits of water diesel emulsion. The most important preference of ferrofluids compared to other nano particles is that magnetic nano particles can be collected at the exhaust of the engine and they will not cause pollution.

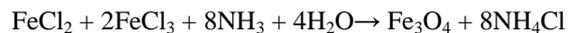
Experimental tests were carried out to investigate the effects of adding oil-based ferrofluid to diesel fuel in a diesel engine.

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These effects included the combustion performance and exhaust emission characteristics of the diesel engine. Emulsified diesel fuels of 0%, 4%, 8% and 12% ferrofluid/diesel ratios by volume were used in a four-stroke diesel engine at rated speed.

## II. FERROFLUID

Ferrofluids are colloidal suspensions of magnetic material in a liquid medium that respond to an external magnetic field. One of the most important features of ferrofluids is their stability, which means that particles in the fluid do not agglomerate and phase-separate even in the presence of strong magnetic fields. The synthesis of ferrofluid was based on reacting iron II ( $\text{FeCl}_2$ ) and iron III ( $\text{FeCl}_3$ ) ions in an aqueous ammonia solution to form magnetite,  $\text{Fe}_3\text{O}_4$ , as shown in the following equation:



The cited procedure claims that those nanoparticles diameters are on the order of 10 nm. Furthermore, aqueous tetra-methyl-ammonium hydroxide ( $(\text{CH}_3)_4\text{NOH}$ ) solution which was used as a surfactant can surround the magnetite particles with hydroxide anions and tetra-methyl-ammonium cations to create electrostatic interparticle repulsion in an aqueous environment

## III. EXPERIMENTAL SETUP AND PROCEDURE

Tests were conducted in the engine using the pure diesel, pure diesel and their various blends, at the rated speed. Starting from no load, the engine was loaded to a load, a little above the rated load. Engine was started and stopped at no load. Enough cooling water supply was ensured. The output power was measured from the energy meter readings, using a stopwatch. The time taken for the consumption of 10cc fuel was also noted. Measurements were taken at no load and then the load was gradually increased to higher values.

Produced ferrofluid mixed diesel was tested in a diesel engine for the performance. Load test was conducted at constant speed and for various percentage of brake power. The setup used for the testing consists of a single cylinder, four-stroke engine, an alternator and an electrical loading arrangement. The alternator is connected to the output shaft of the engine. Bulb type loading was used in the loading arrangement. The various performance measures were found out and plotted against the brake power.

**Table1.** Engine specifications

|                       |                 |
|-----------------------|-----------------|
| Engine Made           | Kirloskar       |
| Bore Diameter         | 80 mm           |
| Stroke Length         | 110mm           |
| No. Of Strokes        | 4               |
| No. Of Cylinders      | 1               |
| Rated Power           | 5 Hp            |
| Rated Speed           | 1500 Rpm        |
| Type Of Cooling       | Water Cooled    |
| Type Of Loading       | Electrical Type |
| Alternator Efficiency | 80%             |

To conduct the engine performance and emission test, the ferrofluid obtained by chemical process is blended with petroleum diesel to get a volume proportion of 4%, 8% and 12% volumetric proportions of ferrofluid. The experiments were conducted at no load, 50% of full load, and 75% of full load conditions with ferrofluid blend and pure diesel operation. Data such as fuel flow, exhaust temperature, exhaust smoke opacity etc were recorded at this condition. Steady state performance and emissions readings are taken during each trial run and the average of the experimental results are used for further calculations.

The NETEL diesel smoke meter is used to measure the opacity of the exhaust gases. Opacity is the extinction of light between light source and photovoltaic receiver. NO<sub>x</sub> and CO emission test were conducted using IR200 Infrared Gas Analyzer

IV. RESULTS AND DISCUSSIONS

**4.1 Engine Performance.** The specific fuel consumption (SFC) and the brake thermal efficiency (BTH) can be calculated by the engine torque, the engine speed, and the mass consumption rate of the fuel. For all fuels, the SFC decreases with an increase in the engine load, while the  $\eta_{BTH}$  increases with the increase in engine load for all different fuels. This is obvious from the fact that the increase in fuel required to operate the engine is less than the increase in brake power at higher loads. Adding a ferrofluid to diesel fuel will decrease the SFC. According to experimental results, adding 4% ferrofluid to diesel fuel decreased the SFC relatively by 6.06 – 9.09%, adding 8% ferrofluid to diesel fuel decreased the SFC relatively by 8.00 – 15.15% and adding 12% ferrofluid to diesel fuel decreased the SFC relatively by 10.52 – 18.18. The decrease in SFC can be due to the positive effects of nano particles on physical properties of fuel and also reduction of the ignition delay time, which lead to more complete combustion. In addition, it can be due to effects of nano particles on fuel propagation in the combustion chamber. On the other hand, nano particles added to diesel fuel increase the mixture momentum and, consequently, the penetration depth in the cylinder. As a result, combustion is improved.

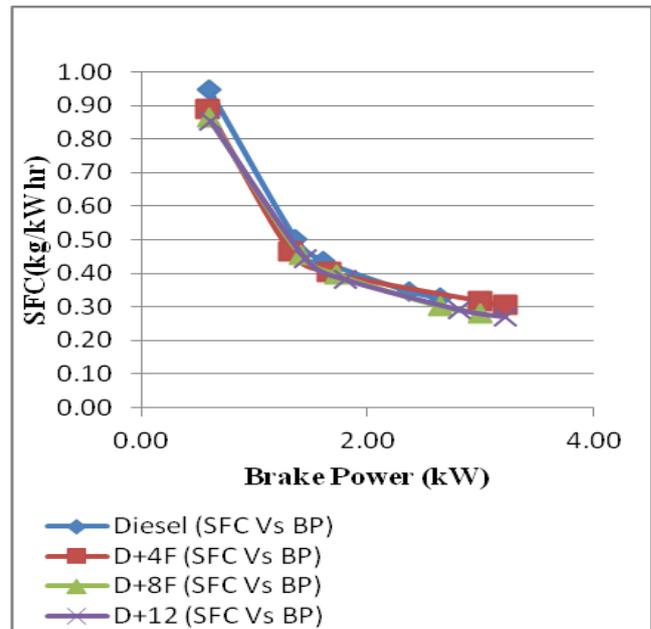


Figure 1.variation of SFC with respect to BP at rated speed

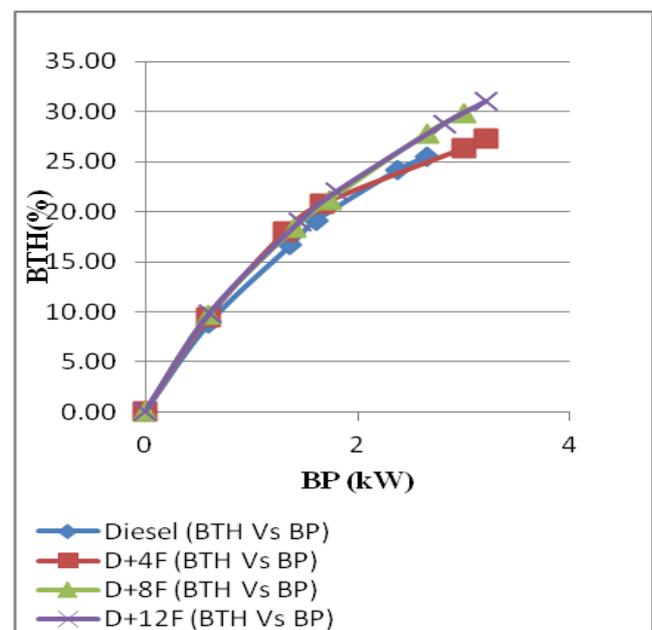


Figure 2.variation of BTH with respect to BP at rated speed

In addition, the higher viscosity of the emulsified fuel than that of the base fuel and the presence of water promote a finer, cloud-like atomization of the emulsified mixture during injection, resulting in improving combustion efficiency significantly. It has been claimed that the water in the emulsified fuel improves the combustion process owing to the simultaneous additional braking of the droplets, to the increase in evaporation surface of the droplets and to better mixing of the burning fuel in air. BTH is dependent on SFC, and thus the BTH of D+4F, D+8F and D+12F improved compared to diesel fuel for the same reasons., BTH increases with an increase in load for each fuel. Adding 4% ferrofluid to diesel fuel increased the BTH by 6.21 – 9.10 % relatively, adding 8% ferrofluid to diesel fuel increased the BTH by 9.6 – 16.69 % relatively and adding 12% ferrofluid to diesel fuel

increased the BTH by 11.07 – 21.43 %. Based on the results, it can be concluded that adding ferrofluid to diesel fuel has a perceptible effect on engine performance.

**4.2 NO<sub>x</sub> Emissions.** The variation of nitrogen oxides (NO<sub>x</sub>) emissions with load for different fuels. NO<sub>x</sub> emissions increase with engine load for all fuels. Furthermore, compared with diesel fuel, D+4F, D+8F and D+12F decreased NO<sub>x</sub> emissions at all loads. Adding 4% ferrofluid to diesel fuel decreased NO<sub>x</sub> emissions by 8 to 21 ppm, adding 8% ferrofluid to diesel fuel decreased NO<sub>x</sub> emissions by 12 to 25 ppm and adding 12% ferrofluid to diesel fuel decreased NO<sub>x</sub> emissions by 17 to 30 ppm. Many factors contribute to the formation of NO<sub>x</sub> emissions. According to the Zeldovich mechanism, the formation of NO<sub>x</sub> is dependent on oxygen concentration, residence time, and temperature. This reduction may be due to the latent heat of evaporation of water, the high thermal capacity of water, and also nano particles, which can reduce the temperature in the combustion chamber and consequently reduce NO<sub>x</sub> emissions.

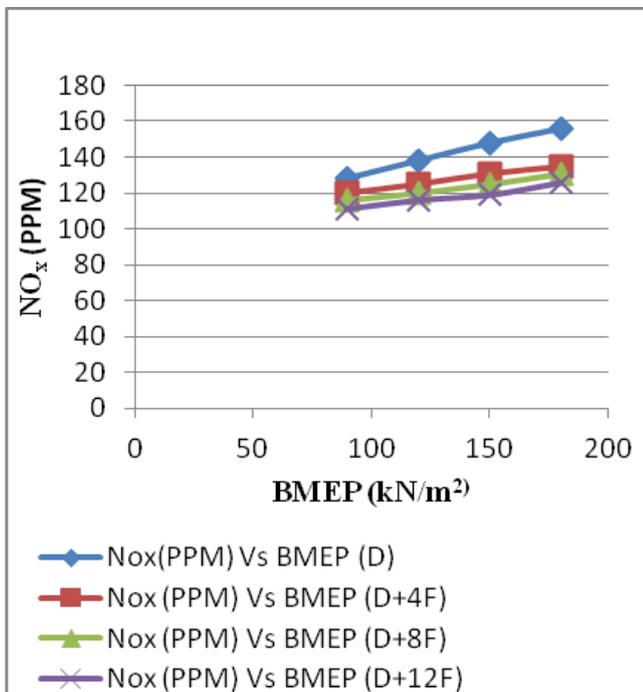


Figure 3. Variation of NO<sub>x</sub> emission with respect to BMEP at rated speed

**4.3. CO Emissions.** Adding ferrofluid to diesel fuel increases CO emissions. Adding 4% ferrofluid to diesel fuel increased CO emissions 11 to 18 ppm, adding 8% ferrofluid to diesel fuel increased CO emissions by 23 to 32 ppm and adding 12% ferrofluid to diesel fuel increased CO emissions by 30 to 43 ppm. CO emission greatly depends on the air-to-fuel ratio relative to stoichiometric proportions. Generally, CI engines operate with lean mixture, and hence CO emissions would be low. Nano particles may have affected fuel propagation in the combustion chamber. The increase in CO emission may be due to operation of the engine using D+4F, D+8F and D+12F in different situation compared to diesel fuel.

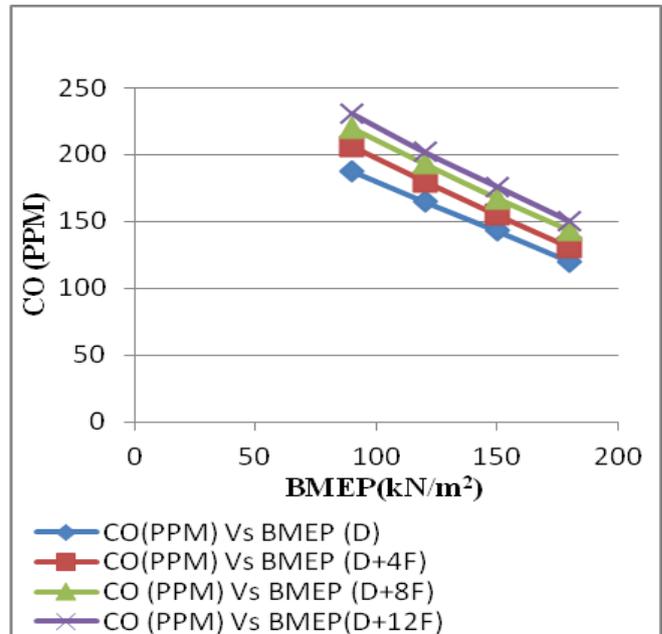


Figure 4. Variation of CO emission with respect to BMEP at rated speed

## V. CONCLUSION

Experimental measurements and analysis were conducted on a four-stroke diesel engine to investigate the effects of adding water-based ferrofluid to diesel fuel. Engine tests were done for emulsified diesel fuels of 0%, 4%, 8% and 12% ferrofluid/diesel at 15000 rpm.

The test results indicated that adding ferrofluid to diesel fuel not only improves engine performance (increasing BTH and decreasing SFC) but also reduces NO<sub>x</sub> emissions. The results showed that increasing ferrofluid concentration will magnify the results.

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