VOL. 4, NO. 8, OCTOBER 2009 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences


www.arpnjournals.com

NOx AND HC EMISSION CONTROL USING WATER EMULSIFIED DIESEL IN SINGLE CYLINDER DIESEL ENGINE

K. Kannan[1] and M. Udayakumar[2]
[1]Department of Mechanical Engineering, Anjalai Ammal-Mahalingam Engineering College, Kovilvenni, TN, India
[2]Department of Mechanical Engineering, National Institute of Technology, Tiruchirappalli, TN, India
E-Mail: kannansurya2003@yahoo.co.in

ABSTRACT

This paper reports on the effect of water emulsified diesel fuel combustion on brake thermal efficiency, brake specific fuel consumption and NOx and hydrocarbon emissions in a diesel engine. The experiments were conducted on a single cylinder four stroke cycle direct injection diesel engine at constant speed with a fuel injection pressure of 200 bars. Tests were conducted using commercial diesel fuel and diesel fuel with 10% and 20% water by volume. From the test results, it was found that the water emulsification has a potential to improve brake thermal efficiency and brake specific fuel consumption. The NOx and hydrocarbon emissions were found to decrease with increase in water percentage in the emulsified diesel.

Keywords: diesel engine, water emulsified diesel, brake thermal efficiency, NOx emission, hydrocarbon emission.

1. INTRODUCTION

Diesel engines have been used in heavy duty applications for a long time; it is only during the past decade that it has become popular in light duty application due to their higher fuel efficiency. 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 NOx 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 NOx and particulate matter (PM). The mechanism of formation of NOx and particulate matter in the combustion chamber of diesel engines are contradictory 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. One promising method may be the use of water emulsified diesel which can economically accomplish both of these goals. 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 proven benefit of the water emulsified diesel is that the heat absorption by water vaporization causes a decrease of local adiabatic flame temperature and therefore reduces the chemical reaction in gas phase to produce thermal NO [4]. Fuel with a larger emulsion ratio results in a longer ignition delay and a longer premixed combustion phase. A higher content of water weakens luminous flames and reduces the peak temperature in the diffusion controlled combustion phase and leads to a lower peak pressure and a lower level of NOx emission [5]. The brake thermal efficiency increase and brake specific fuel consumption is found to decrease as the amount of water in the emulsion increased [3]. Hsu [6] reported that smoke and NOx emissions decrease as the water amount in emulsion is increased and the maximum pressure did not change significantly at all load conditions of investigation.

In this experimental work, the effects of water percentage in the water emulsified diesel are investigated on performance and emission characteristics in a light duty single cylinder direct injection diesel engine.

2. MATERIALS AND METHODS

The experiments were conducted on a single cylinder Kirloskar make direct injection four stroke cycle diesel engine. The general specifications of the engine are given in Table-1. Water cooled eddy current dynamometer was used for the tests. The engine is equipped with crank angle sensor, piezo-type cylinder pressure sensor, thermocouples to measure the temperature of water, air and gas. Rotameter is used to measure the water flow rate and manometer is used to measure air flow and fuel flow. All the measured readings are fed to computer using a 12 bit add on card to analyze the results. Engine performance analysis software "Engine soft" is used to analyze and plot the graphs.

Table-1. Engine specifications.

Item	Specifications
Engine power	5.2 kW
Cylinder bore	87.5 mm
Stroke length	110 mm
Connecting Rod Length	234 mm
Engine speed	1500 rpm
Compression ratio	17.5
Fuel injection pressure	200 bar

An exhaust gas analyzer model QRO 402 was used to measure CO, HC, CO_2, O_2, and NOx. The measuring range and resolution are given in Table-2.

Table-2. Exhaust gas analyzer specifications.

Measuring item	Measuring method	Measuring range	Resolution
CO	NDIR	0 -9.99 %	0.01%
HC	NDIR	0 -5000 ppm	1 ppm
CO_2	NDIR	0-20 %	0.10%
O_2	Electrochemical	0-25 %	0.01%
NOx	Electrochemical	0-5000 ppm	1 ppm

The water emulsified diesel fuel was prepared by mixing 10% and 20% of distilled water with 90% and 80% of diesel by volume, respectively. Sodium lauryl sulphate was used as surfactant to prepare emulsion. Sodium lauryl sulphate (0.1%) is added with 100 ml and 200 ml distilled water and mixed with 900 ml and 800 ml diesel to prepare D10 and D20 emulsified diesel fuels, respectively. The mixer was stirred for 2-3 minutes in an electrically operated agitator.

The experiments were performed at constant speed of 1500 rpm. The engine was loaded by eddy current dynamometer and the load was measured using a strain gauge. The air consumption is measured with an air manometer surge tank set which has orifice diameter of 20 mm.

3. RESULTS AND DISCUSSIONS

The aim of the experimental study was to investigate the effect of diesel (DSL), diesel with10% water (D10) and diesel with 20% water (D20) on performance and emission in a light duty single cylinder diesel engine. The experimental results are presented in Figures 1 to 4.

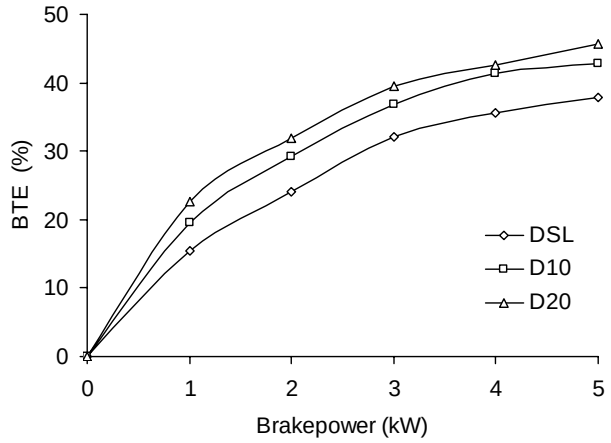

Figure-1. Brake power Vs brake thermal efficiency.

The effect of water percentage in diesel-water emulsion on brake thermal efficiency is shown in Figure-1. When the amount of water in the emulsion increases the brake thermal efficiency increases. The presence of water in the emulsion increases the expansion work and reduces the compression work resulting increased net work done during the cycle. The expansion of water vapor offers additional force on the top of the piston which increases the torque produced during the cycle. In the diesel-water emulsion, the diesel quantity is replaced by equal amount of water per unit volume. So, the increase in net work done and decrease in fuel consumption causes higher brake thermal efficiency. This is in agreement with Abu-Zaid [3] who experimentally showed that the maximum brake thermal efficiency occurs when 20% water in the emulsion is used in a single cylinder diesel engine. Jamil Ghojel *et al*., [1] also reported that the brake thermal efficiency of diesel oil emulsion is somewhat higher over the test range in heavy duty industrial diesel engine. For a light duty IDI diesel engine, the use of emulsified fuel improves the engine efficiency in certain operating modes [4].

The brake specific fuel consumption (BSFC) decreases at all load conditions when the percentage of water in the emulsion is increased as shown in Figure-2. As the percentage of water in the emulsion increases, the amount of diesel is replaced by an equal amount of water. This means that less diesel fuel is actually contained in unit volume of the emulsion. So, as the percentage of water in the emulsion increases, the BSFC decreases. The minimum value occurs when the percentage of water is 20% [3]. When the emulsified fuel is used, the most probable reason to obtain improvement in brake specific fuel consumption and thermal efficiency is the reduction of heat losses [4].

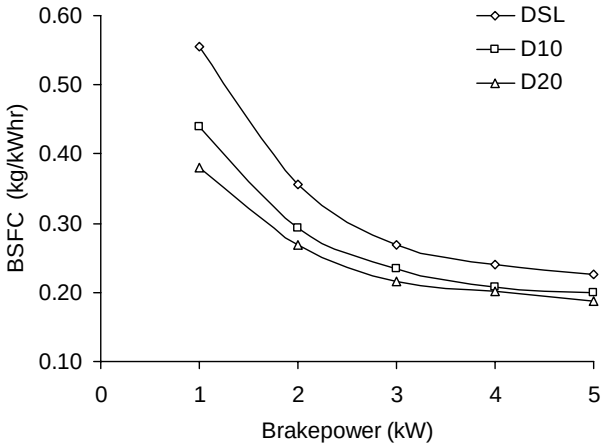

Figure-2. Brake power vs brake specific fuel consumption.

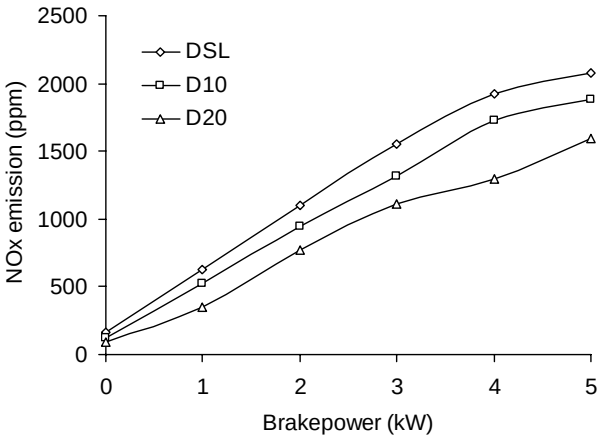

Figure-3. Brake power vs NOx emission.

The NOx emission decreases with the percentage of water in the emulsion as shown in Figure-3 at all load conditions. The percentage of reduction in NOx is 10% and 25% for 10% and 20% water in the emulsion. The improvement in the NOx emission is caused by the reduction in adiabatic flame temperature due to the vaporization and sensible heats of water. The presence of water in the emulsion weakens luminous flames and reduces the peak temperature during diffusion-controlled combustion phase which leads to a lower peak pressure and a lower level of NOx emission [5].

The presence of hydrocarbon (HC) in exhaust gases at 10% and 20% water in the emulsion is shown in Figure-4. At all load conditions the presence of HC in exhaust gases is found decreasing with increase in water percentage in the emulsion. This observation is consistent with Armas [4] who attributed this to micro-explosion. The micro-explosion phenomenon in emulsified fuel due to the volatility differences between water and diesel fuel causes violent disintegration of fine droplets and consequently enhances the fuel-air mixing in the combustion chamber helps in reducing the formation of soot and HC. Additionally, the increased amount of OH radicals from water dissociation also reduces the formation of soot because high radical concentration promotes carbon oxidation, thereby limiting carbon availability for the formation of soot precursors.

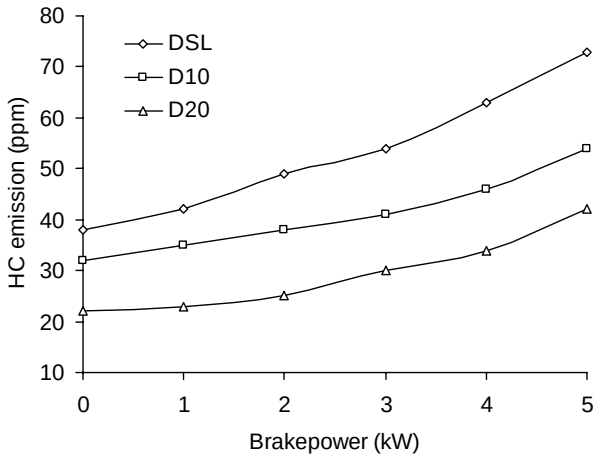

Figure-4. Brake power vs. hydrocarbon emission.

4. CONCLUSIONS

From the experimental result reported here, it is concluded that use of water emulsified diesel fuel has a potential to improve the performance and emission characteristics of diesel engine. The test results show good agreement with previous study for emulsified fuel referred in the literature. Switching to emulsified fuel combustion does not require any engine modification. The corrosion of engine components due to water presence in the emulsion could be a problem in long run operation of the engine. But, Kweonha Park *et al.*, [7] argued that water in the oil was quickly evaporated by micro-explosion into extremely tiny droplets; this would make the water droplets not to reach directly to the combustion chamber wall, so there would be no corrosion on the cylinder surface.

REFERENCES

[1] Jamil Ghojel, Damon Honnery, Khaled Al-Khaleefi. 2006. Performance, emission and heat release characteristics of direct injection diesel engine operating on diesel oil emulsion. Applied Thermal Engineering. 26: 2132-2141.

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

[3] M. Abu-Zaid. 2004. Performance of single cylinder, direct injection diesel engine using water fuel emulsions. Energy Conversion and Management. 45: 697-705.

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

[5] J.W. Park, K.Y. Huh, J.H. Lee. 2001. Reduction of NOx, smoke and brake specific fuel consumption with optimal injection timing and emulsion ratio of water-emulsified diesel. Proc. Instn. Mech. Engrs. 215: 83-93.

[6] Bertrand D. Hsu. Combustion of water-in-diesel emulsion in an experiment medium speed diesel engine. SAE. 860300. pp. 2285-2295.

[7] Kweonha Park, Inseok Kwak, Seungmook Oh. 2004. The effect of water emulsified fuel on a motorway-bus diesel engine. KSME International Journal. 18: 2049-2057.