EMISSION CONTROL BY USING WATER EMULSIFIED DIESEL IN SINGLE CYLINDER DIESEL ENGINE

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ABSTRACT

This paper reports on the effect of water emulsified diesel fuel combustion on brake thermal efficiency, brake specific fuel consumption, oxides of Nitrogen (NOx) and Hydrocarbon emissions in a diesel engine. The experiments were conducted on a single cylinder four stroke cycle diesel engine. The experiment was carried out with the 10% and 20% water blended diesel by taking Polysorbate 20 as solvent. Tests were performed using a commercial fuel as a reference and an emulsified fuel for each operating condition. Results reported here suggest that the water emulsification has a probable to improve brake thermal efficiency and break specific fuel consumption. Emulsions of diesel and water are often promoted as being able to overcome the difficulty of simultaneously reducing emissions of both oxides of nitrogen (NOx) and hydro carbon emissions in a diesel engine.

KEYWORDS: *Diesel, Efficiency, Emission, Engine, Polysorbate 20.*

I. INTRODUCTION

In this modern world of industries and technology the diesel engine plays a major role in various fields. It may be transportation or production etc., with the increase of various applications to the diesel resources effects on the environment leading to result like green house effect. Higher fuel efficiency in the diesel engine is achieved due to the high compression ratios along with relatively high oxygen concentration I the combustion chamber. However, these same factors results in high oxides of nitrogen (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 oxides of nitrogen (NOx) and particulate matter (PM). High temperature and availability of oxygen are 2 main reasons of formation of oxides of nitrogen (NOx). These are direct results of incomplete combustion. Hydrocarbon levels are higher during high speed deceleration, idling and low speed operation. A progressive 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 oxides of nitrogen (NOx) emission. The brake thermal efficiency increase and brake specific fuel consumption, oxides of nitrogen (NOx) and Hydro carbons (HC) are found to decrease. The available literature giving information regarding various types of research works, for example improvement of fuel mixture (Boehner et al,. 1997), development of alternative fuels (Graboski et al,.1998) and stabilization of engine to controlled emission (Khalek et al,.1998). The present work can be considered as development of alternative fuels. The studies reporting that, an experimental investigation about the influence of water–diesel emulsifying on the main pollutant emissions, namely emissions of both oxides of nitrogen (NOx) and hydro carbon emissions in single cylinder Alamgir four stroke cycle diesel engine was controlled. All the reviewed works about preparation and use of water–Diesel emulsions and the effects of this fuel on the engine performance and emissions. In general, the main conclusions of these works can be summarized as follows.

II. RELATED WORK

Hues research has been going on water emulsified diesels among the world. This is in agreement with Abu-Zaid 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., (2006) also reported that the brake thermal efficiency of diesel oil emulsion is 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. M. Uday Kumar and K. Kannan(2009) were reported that brake thermal efficiency and brake specific fuel consumption is found to be controlled with the percentage of water increase in the diesel emulsion and reported that smoke and NOx emissions decrease as the water amount in emulsion is increased.

III. EXPERIMENTAL SET UP

The experiments were conducted on a single cylinder Alamgir four stroke cycle diesel engine, a schematic diagram of ingine setup has been shown in Fig 1. All sets are naturally aspired and hand start. Electric start arrangements can be provided optionally. Details of the custom built sets such as Silent Generated set /AMF sets etc available on request. Above specification are subjects to change as continuous improvements are carried out in products .S.F.C calculated at 80% load are representative figure and would vary on quality fuel, site condition, actual load applied etc. “ALAMGIR” Diesel Generated sets are available in both Air cooled models.

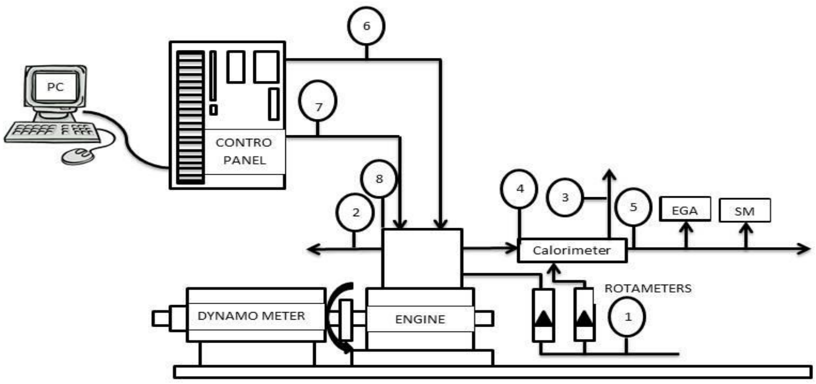

Figure1. Experimental set up. (1-Water inlet to the calorimeter and engine (T10C), 2. Water outlet from the engine jacket (T20C), 3. Water outlet from the calorimeter (T30C), 4. Exhaust gas inlet to the calorimeter (T40C), 5. Exhust gas out let from the calorimeter (T50C). 6. Atmospheric air temperature ((T60C), 7. Fuel flow, 8. Pressure Transducer, EGA. Exhaust gas analyzer, SM. Smoke Meter)

They range from 2KVA to 25KVA. “ALAMGIR” Generated sets operator at 100% declare ratings. The generated sets are designed to minimize servicing points, simplify maintains procedure and emphasize repair accessibility. With more than three decades of experience in designing, manufacturing and innovating in the world of generated sets, the name has become synonymous with high quality diesel generating sets. The generated sets are designed to operate with high fuel efficiency.

3.1: Engines

“ALAMGIR” engines for generating sets are fuel efficient, with the lubricating oil consumption less than 1% of S.C.F. lowest among the comparable brands. They are equipped with heavy flywheels incorporating 4% governing on the fuel injection equipment and it avoids voltage functions. In case of emergency, the unique overload stop feature safeguards equipments by shutting down the engine automatically. The general specifications of the engine are given in Table 1.

Table 1 Engine Specifications

Genset rating	4 kva
Phase	1 ph
Engine Model	atf-1
Cooling	Air
Starting system	hs/es
No. of cylinders	1
Engine bhp	9
Engine power	6.6 kw
Cylinder bore	102 mm
Stroke length	110 mm
Connecting rod length	234 mm
Engine speed	1500 rpm
Compression ratio	17.5

By taking the engine performance and plot the graphs. An exhaust gas analyzer 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

S. No	Measuring item	Measuring method	Measuring Range	Resolution
1	CO	NDIR	0-9.99%	0.01%
2	HC	NDIR	0-5000ppm	1ppm
3	CO_2	NDIR	0-20%	0.10%
4	O_2	Electrochemical	0-25%	0.01%
5	NO_X	Electrochemical	0-5000ppm	1ppm

The water emulsified diesel fuel was prepared by mixing 10%, 20% and 30% of distilled water with 90%, 80% and 70% of diesel by volume, respectively. The method of emulsified diesel preparation is given in Fig 2.

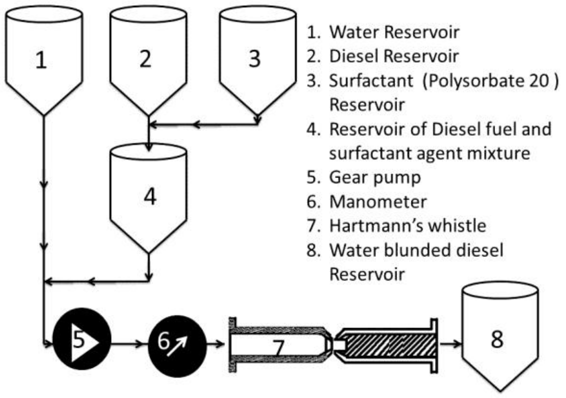

Figure 2: Scheme of the device used for the preparation of emulsified fuel.

Polysorbate 20 was used as surfactant to prepare emulsion. Polysorbate 20 is added 100 ml and 200 ml woth distilled water and mixed with 900 ml and 800 ml diesel respectively to prepare D10 and D20 emulsified diesel fuels. 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 electrical dynamometer.

3.2: Fuel specifications

3.2:1Diesel:

Density	-	850 KG/CUBIC CENTIMETER
Calorific value	-	42,300KJ/KG
Flashpoint	-	48^0 C
Fire point	-	51^0 C

3.2.2: Water emulsified diesel:

a) 10% Water + 0.1 % Tween ® 20 + 89.9 % Diesel

Density	-	831 Kg/Cubic centimeters
Calorific value	-	41,425KJ/KG
Flashpoint	-	51^0 C
Fire point	-	53^0 C

b) 20% Water + 0.1 % Tween ® 20 + 79.9 % Diesel

Density	-	828 Kg/Cubic centimeters
Calorific value	-	43,595KJ/KG
Flashpoint	-	47^0 C
Fire point	-	49^0 C

IV. RESULTS AND DISCUSSIONS

The aim of the experimental study was to investigate the effect of diesel, diesel with10% water(D10), diesel with 20% water(D20) and diesel with 30% water (D30) on performance and emission in a light duty single cylinder diesel engine. The experimental results are presented in Figures 4 to 15. The brake specific fuel consumption (BSFC) decreases at all conditions when the percentage of water in the emulsion is increased as shown in Figure 3.

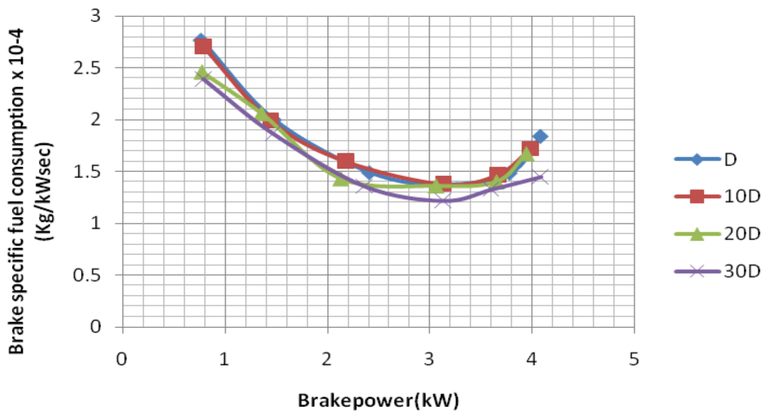

Figure 3. Brake power Vs Brake specific fuel consumption

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 30%. 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. 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 4.

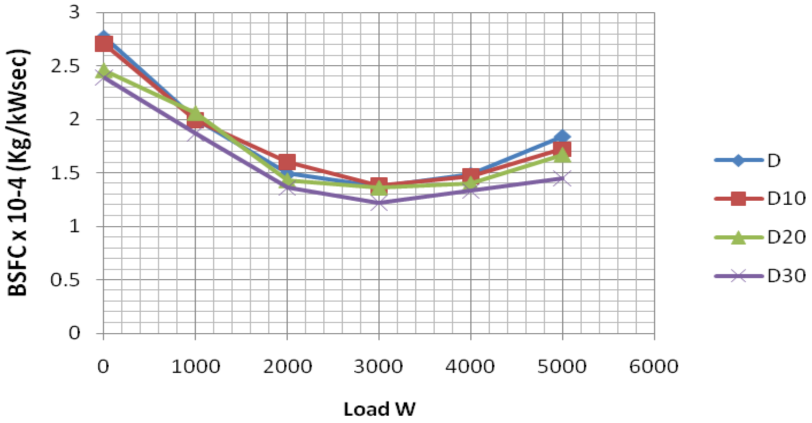

Figure 4. Load Vs Brake Specific Fuel Consumption

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 30%. 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. The Mechanical efficiency decreases at all conditions when the percentage of water in the emulsion is increased as shown in Figure 5.

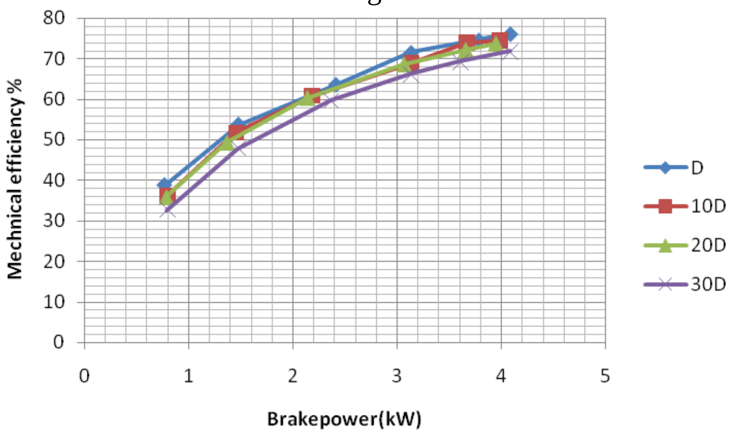

Figure 5. Brake power vs Mechanical efficiency

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 Mechanical efficiency decreases. The minimum value occurs when the percentage of water is 30%. 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. The effect of water percentage in diesel-water emulsion on brake thermal efficiency(BTE) and indicated thermal efficiency (ITE) is shown in Figures 6 and 7.

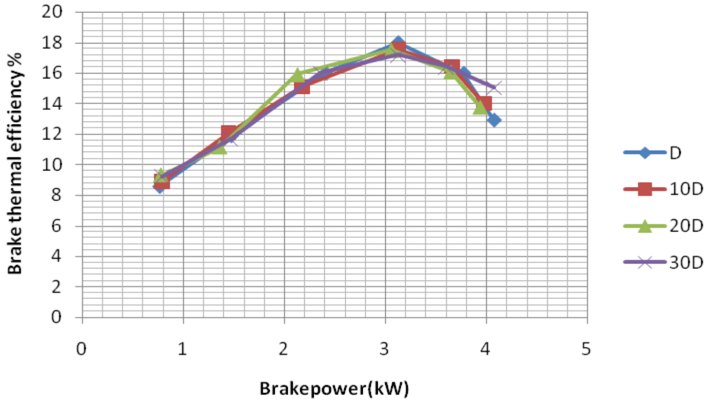

Figure 6: Brake power vs BTE

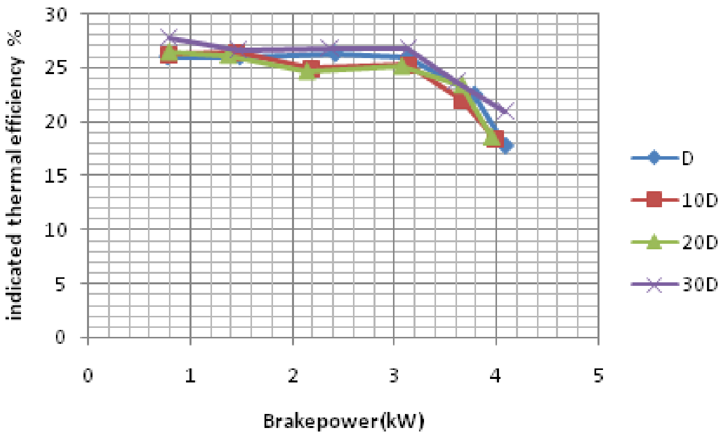

Figure 7. Brake power vs ITE

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 and indicated efficiency. This is in agreement with Abu-Zaid who experimentally showed that the maximum brake thermal efficiency occurs when 30% water in the emulsion is used in a single cylinder diesel engine. Jamil Ghojel et.al.(2006) 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. The brake indicated that, decreases in the load conditions, when the percentage of water in the emulsion is increased as shown in figures 8 and 9.

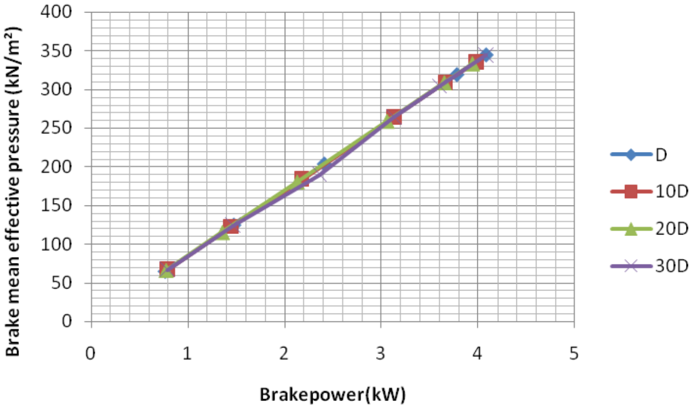

Figure 8. BP vs BMEP

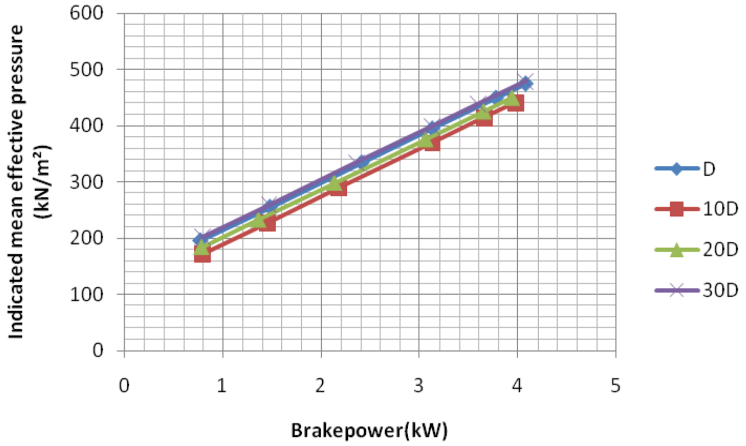

Figure 9. BP vs IMEP

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, then mean effective pressure decrease. The minimum value occurs when the percentage of water is 30%. When the emulsified fuel is used, the most probable reason to obtain improvement in effective pressures The Volumetric efficiency increases at all load conditions when the percentage of water in the emulsion is increased as shown in figures 10 and 11.

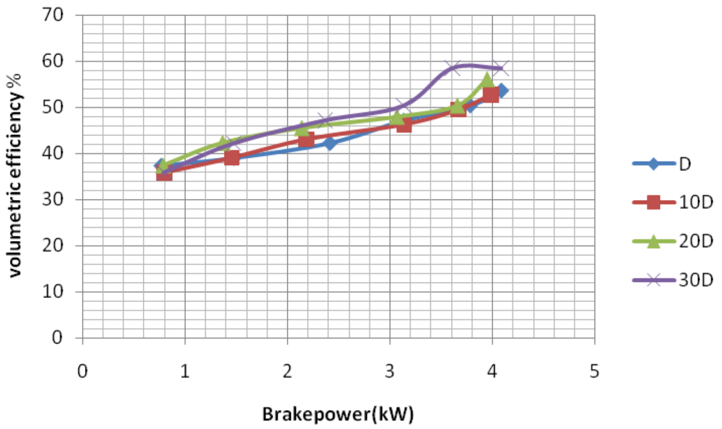

Figure 10. BP vs Volumetric efficiency

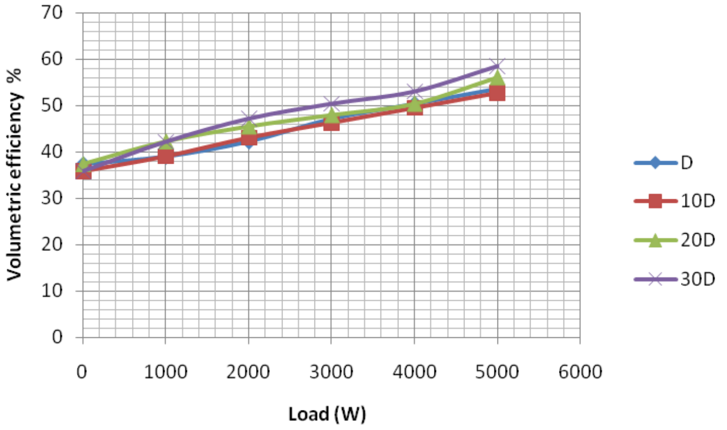

Figure 11. Load vs Volumetric efficiency

So, as the percentage of water in the emulsion increases, then volumetric efficiency increases. The minimum value occurs when the percentage of water is 30%. When the emulsified fuel is used, the most probable reason to obtain volumetric efficiency increases. The Exhaust gas temperature decreases at all load conditions when the percentage of water in the emulsion is increased as shown in figure 10. Then the combustion takes effective and more efficiency. So, as the percentage of water in the emulsion increases, then exhaust gas temperature decreases. The minimum value occurs when the percentage of water is 30%. When the emulsified fuel is used, the most probable reason to obtain exhaust gas temperature decreases. The Hartridge smoke unit (Hsu), Hydro carbon (HC), Carbon Monoxide (CO), carbon dioxide (CO2) and Oxygen content are decreases at all load conditions when the percentage of water in the emulsion is increased as shown in figures 12,13,14,15 and16.

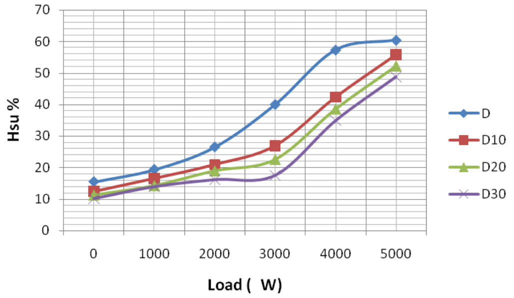

Figure 12. Load vs Hartridge smoke unit

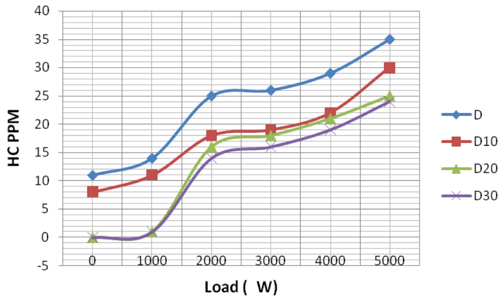

Figure 13. Load Vs HC ppm

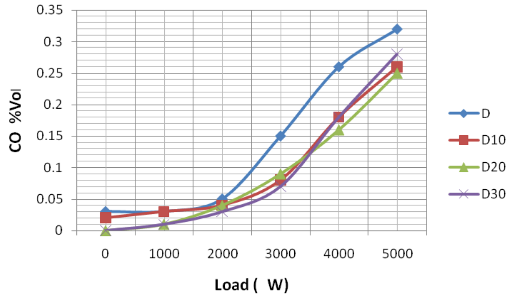

Figure14. Load vs CO % Volume

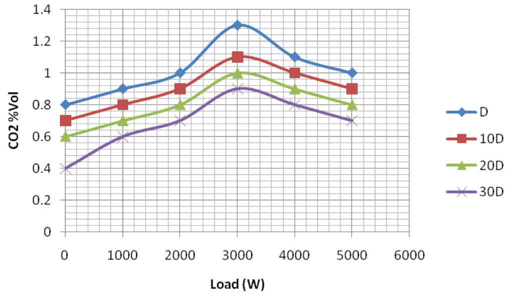

Figure15. Load Vs CO_2% volume

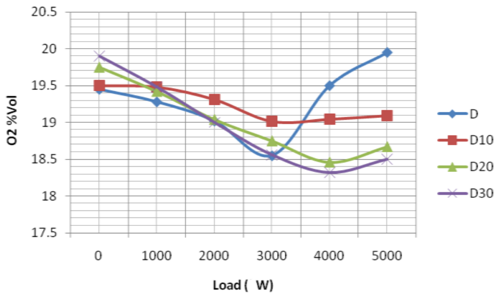

Figure16. Load vs O_2% volume

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, then pollutants decrease. The minimum value occurs when the percentage of water is 30%. When the emulsified fuel is used, the most probable reason to obtain improvement in Engine Emissions

Polysorbate 20(commercially also known as **Tween 20**) is a polysorbate surfactant whose stability and relative non-toxicity allows it to be used as a detergent and emulsifier in a number of domestic, scientific, and pharmacological applications. It is a polyoxyethylene derivative of sorbitan monolaurate, and is distinguished from the other members in the Tween range by the length of the polyoxyethylene chain and the fatty acid ester moiety. The commercial product contains a range of chemical species. Tween 20's cmc is 8.04×10^{-5} M at 21°C. This corresponds to 0.0987 g/L or approximately 0.1 ‰ w/v. Tween 20's hydrophile-lipophile balance (HLB) is 16.7. HLB number is a measure of how much a surfactant will move into the water and oil phase. A high HLB number indicates that a surfactant will convert into the water phase, where 16.7 is a high number.

V. CONCLUSIONS

A water–Diesel emulsion was studied in single cylinder Alamgir four stroke cycle diesel engines to clarify the changes in the main pollutant emissions. The use of the emulsified fuel improves the engine efficiency in certain operating modes. This result confirms the necessity of a more exhaustive study combining emulsion characteristics with tuning of engine parameters. For the operating modes studied here, a reduction of the measured pollutant was observed when the emulsion was used. In general, the results reported here suggest that the water emulsification has a potential to slightly improve the Emulsions of diesel and water are often promoted as being able to reducing emissions of both oxides of nitrogen (NOx) and hydro carbon emissions in a diesel engine. Further, experimental work for optimising the emulsion formulation in terms of water content and internal structure is recommended.

VI. FUTURE SCOPE

Planned research includes further testing and refinement of the fuel emulsification additives to have still better results of emissions. As shown by Montagne et al. (1987), adding surfactants to fuel can increase emissions of NOx. To minimize both increased emissions and fuel costs due to surfactants, one should use the minimum level of surfactant necessary to stabilize the fuel—water mixture. A factorial analysis should be conducted varying fuel, water, surfactant, and other additive concentrations to determine first- and second-order effects. The mixing time required to develop a stable emulsion is best determined empirically. Again, a factorial analysis varying the water and fuel ratios versus mixing power and time should be conducted to establish a matrix of mixing times required to guarantee a stable emulsion. The need for a corrosion inhibitor should be quantified through visual and wear-metal testing on engine components after extended use of fuel—water blends both with and without a corrosion inhibitor. The added cost of the corrosion inhibitor should be firmly established and demonstrated as a necessity to protect the engine and components, not simply a precaution to subdue suspicions of corrosion potential. If a corrosion inhibitor is demonstrated as necessary, GC/MS analysis of exhaust emissions across all load ranges should be conducted to determine if corrosion inhibitor components are emitted from the engine.

REFERENCES

[1]. Boehner W, Hummel K. Common rail injection system for commercial diesel vehicles. SAE paper 970345; 1997.
[2]. Graboski MS, McCormick RL. Combustion of fat and vegetable oil derived fuels in diesel engines. Prog Energy Combust Sci, Vol. No. 24., pp.125–641., 1998.
[3]. Abdul-Khalek IS, Kittelson DB, Graskow BR, Wei Q, Brear F. Diesel trap performance: particle size measurement and trends. SAE paper 982599; 1998.
[4]. K Kannan and M Udayakumar, NOx and HC Emission control using water emulsified diesel in single cylinder diesel engine, ARPN Journal of Engineering and Applied Sciences, Vol. No. 4., Issue 8., pp 59 – 62., 2009.
[5]. Jamil Ghojel, Damon Honnery and Khaled Al-Khaleefi, Performance, emission and heat release characteristics of direct injection diesel engine operating on diesel oil emulsion, Applied Thermal Engineering, Vol. No. 26., pp 17 – 18, 2132 – 2141., 2006.
[6]. J. W. Park, K.Y. Huh and K.H. Park, Experimental study on the combustion characteristics of emulsified diesel in a rapid compression and expansion machine, Proc. Instn. Mech. Engrs, Vol. No. 214., pp. 579 – 585., 2000.
[7]. M. Abu-Zaid, Performance of single cylinder, direct injection diesel engine using water fuel emulsions, Energy Conversion and Management, Vol. No.45., Issue 5., pp. 697 – 705., 2004.
[8]. O. Armas, R. Ballenseros, F.J. Martos and J.R. Agudelo, Characterization of light duty diesel engine pollutant emissions using water-emulsified fuel, Fuel, Vol.No. 84., pp. 1011 – 1018., 2005.
[9]. C. Alan Canfield, Effects of diesel—water emulsion combustion on diesel engine NOx emissions, A Thesis Presented To The Graduate School Of The University Of Florida In Partial Fulfillment of The Requirements For The Degree Of Master Of Science University Of Florida, 1999.
[10]. H.B. Urbach, D.T. Knauss and J. Emory, The Reduction of NOx Emissions from Marine Power Plants", Proceedings of the Air & Waste Management Association's 90th Annual Meeting & Exhibition, Toronto, Ontario, Canada, pp. 97., 1997.
[11]. U.S. EPA, Determination of Nitric Oxide, Nitrogen Dioxide and NOx Emissions from Stationary Sources by Electrochemical Analyzer, Emission Measurement Center (EMTIC), Technical Support Division, Office of Air Quality Planning and Standards, Research Triangle Park, NC. 1995.
[12]. E. Valdmanis and D.E. Ulforst. The Effect of Emulsified Fuels and Water Induction on Diesel Combustion, SAE Paper, 700736., 1970.
[13]. R. Vichnievsky, Use of Water-Fuel Emulsions in Diesel Engines, 11th Congress (Int) on Combustion, Barcelona Spain, May 1975.
[14]. Charles K. Westbrook, Chemical Kinetics and Modeling of Combustion Processes, Symposium (International) on Combustion, Vol. No. 18., Issue 1., pp. 749 – 767., 1981.
[15]. H. Yanagihara, Simultaneous Reduction of NOx and Soot in Diesel Engines Using a New Mixture Preparation Method, JSME . International Journal, Series B, Vol. No.40., Issue 4., pp. 592 – 598., 1997.
[16]. S. Yoshihara, M. Okabe and T. Nakamaura, Water Injecting Type Diesel Engine, U.S. Patent, United States Patent Office, Vol. No.5., Issue 522., pp.349., 1996.
[17]. X Montagne, D. Herrier, and J-C. Guibet, "Fouling of Automotive Diesel Injectors Test Procedure, Influence of Composition of Diesel Oil and Additives," SAE Paper 872118., 1987.

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