Performance Evaluation of Water Emulsion Fuel used in Internal Combustion Engine

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Abstract: In this paper the performance characteristics like specie fuel consumption, brake thermal efficiency and emissions control parameters of compression and spark ignition engines of water emulsion mixed with diesel and petrol fuel were been reviewed by various authors were presented.

Keywords: spark ignition, water emulsion and thermal efficiency.

1. INTRODUCTION:

K.A. Subramanian [1] presented in their technical paper effects of water–diesel emulsion and water injection into the intake manifold on performance, combustion and emission characteristics of a DI diesel engine under similar operating conditions. The water to diesel ratio for the emulsion was 0.4:1 by mass. The same water–diesel ratio was maintained for water injection method in order to assess both potential benefits. All tests were done at the constant speed of 1500 rpm at different outputs. The static injection timing of 23° BTDC was kept as constant for all experimental tests. In the first phase, experiments were carried out to assess the performance, combustion and emission characteristics of the engine using the water–diesel emulsion. The emulsion was prepared using the surfactant of HLB:7. The emulsion was injected using the conventional injection system during the compression stroke. The second phase of work was that water was injected into the intake manifold of the engine using an auxiliary injector during the suction stroke. An electronic control unit (ECU) was developed to control the injector operation such as start of injection and water injection duration with respect to the desired crank angle. The experimental result indicates the both methods (emulsion and injection) could reduce NO emission drastically in diesel engines. At full load, NO emission decreased drastically from 1034 ppm with base diesel to 645 ppm with emulsion and 643 ppm with injection. But, NO emission reduction is lesser with injection than emulsion at part loads. Smoke emission is lower with the emulsion (2.7 BSU) than with water injection (3.2 BSU) as compared to base diesel (3.6 BSU). However, CO and HC levels were higher with emulsion than water injection. As regards NO and smoke reduction, the emulsion was superior to injection at all loads. Peak pressure, ignition delay and maximum rate of pressure rise were lesser with water injection as compared to the emulsion. It is well demonstrated through this comparative study that the emulsion method has higher potential of simultaneous reduction of NO and smoke emissions at all loads than injection method. Ali M.A. Attaa, A.R. Kulchitskiy [2] presented in their technical paper the effect of the structure of water-in-diesel fuel emulsion (WFE) on a three cylinder diesel engine performance has been investigated. Based on membrane emulsification, two different membranes of pore sizes of 0.2 μm and 0.45 μm has been individually used to change the emulsion structure while keeping the same WFE volumetric content (at 17% water volumetric content and 0.5% mixing emulsifier content). The Results showed that emulsions with large size of water droplets resulted in greater reduction in NOx emissions up to 25%. While, emulsions with finer droplets not only gave reductions in engine smoke and unburned hydrocarbons of values greater than 80% and 35% respectively, but also resulted in an increase of the engine effective efficiency up to 20%. Alain Maiboom, Xavier Tauzia[3] presented in their technical paper an experimental study was conducted on a modern automotive 1.5 l HSDI Diesel engine while injecting a water-in-diesel emulsion (WDE) with a volumetric water-to-fuel ratio of 25.6%. Four injection strategies are considered with and without pilot injection, with two levels of injection pressure. First, the injection of WDE was compared to diesel-fuel in terms of combustion and NOx and PM emissions without using exhaust gas recirculation (EGR). Depending on the WDE fuelling rate and injection strategy (with or without a pilot injection before main injection), NOx emissions are most often reduced (of up to 50%), and PM emission are most often decreased as well (the maximum relative reduction being 94%). The combustion was largely affected by the injection of WDE as compared with pure diesel-fuel, the main observations being an increased of the ignition delay and an improved mixing-process between the fuel and the surrounding gases. After that, the use of WDE in parallel with EGR (with various EGR rates) was tested with the aim at improving the NOx–PM trade-off (reduction of NOx emission at a given PM emission level or reduction of PM emission at a given NOx emission level). The results show that this method was an effective way for NOx and PM emission reduction on an automotive Diesel engine.

biodiesel and the micro-emulsions as fuels under variable operating conditions. The results indicate that, compared with biodiesel, the peak cylinder pressure of the micro-emulsions was almost identical, and the peak pressure rise rate and peak heat release rate are higher at medium and high engine loads. At low engine loads, those of the micro-emulsions are lower. The start of combustion was later for the micro-emulsions than for biodiesel. For the micro-emulsions, there was slightly higher brake specific fuel consumption (BSFC), while lower brake specific energy consumption (BSEC). Drastic reduction in smoke was observed with the micro-emulsions at high engine loads. Nitrogen oxide (NOx) emissions are found slightly lower under all range of engine load for the micro-emulsions. But carbon monoxide (CO) and hydrocarbon (HC) emissions are slightly higher for the micro-emulsions than that for biodiesel at low and medium engine loads.

Ming Huo, Shenlun Lin, Haifeng Liu, Chia-fon F. Lee [5] presented in their technical paper emulsified diesels with 10% and 20% water by volume were studied. The stability of the water emulsified diesel was first investigated in terms of the hydrophilic-lipophilic-balance (HLB) value. Based on the stability test, a suitable surfactant composition for the diesel/water interfacial condition was given and the separation tendency of the fuel with different water volumetric ratio was analyzed. The emulsions were later injected and combusted in a pre-burn type constant volume chamber, which was able to provide high ambient temperature and pressure to mimic real engine operation conditions. High speed imaging was used to capture the spray and combustion process under various conditions. Results show longer initial liquid penetration for emulsified diesel under low ambient temperatures. Longer ignition delay of emulsified diesel also provided more air/fuel mixing time, thus significantly lowering the soot luminosity. Although droplet micro-explosion has been extensively studied, its behavior in a burning spray was much less reported. This study in particular focused on micro-explosion in a burning spray. Broadband natural flame images were recorded with intentional overall over-exposure so that the central lift-off region could be illuminated by soot incandescence. Puffing and disruptive droplet combustion was consistently observed at high ambient temperature in the central lift-off region with emulsified diesel indicating the occurrence of micro-explosion in a burning spray flame. It is demonstrated that micro-explosion was not only able to enhance the secondary breakup, but also affect the primary breakup under certain conditions, which to the author’s awareness has not been reported in any previous literature. Lower injection pressure and higher ambient temperature favor the occurrence of micro-explosion before primary breakup as a competition between the micro explosion delay time and the primary breakup time. Youcai Liang, Gequn Shu, Haiqiao Wei, Wei Zhang [6] presented in their technical paper oxygen enriched combustion (OEC) was potential to improve emissions, thermal efficiency and brake power output of diesel engine. The purpose of this investigation was to study whether it is feasible to apply water diesel emulsion to mitigate the increasing NOx caused by OEC with comparable BSFC and power output. Effect of OEC on particle size and number concentration was also analyzed in this paper. Oxygen concentration of intake air varied from 21% to 24% by volume. Water content in tested fuels was 0%, 10%, 20%, and 30% by volume respectively. The result indicated that lower BSFC, higher cylinder pressure and shorter ignition delay were observed when OEC was applied, while opposite trends were found when using WDE. Reduction of PM and NOx can be realized simultaneously by applying OE combined with WDE. Particle number concentration of nucleation mode increases with increasing oxygen concentration, while that of accumulation mode decreases. Optimal operating condition was realized when water content in emulsion was below 20% along with low oxygen enrichment.

M. Ebna Alam Fahd, Yang Wenming, P.S. Lee, S.K. Chou, Christopher R. Yap[7] presented in their technical paper experimental study has been conducted to evaluate the effect of 10% water emulsion diesel (ED10) on engine performance and emission, and comparison is made against base diesel fuel. The experiments were performed in a four cylinder 2.5 L DI turbocharged Toyota diesel engine at four different engine loading conditions (25%, 50%, 75% and 100% load). During experiments, the engine speed was varied from 800 rpm to 3600 rpm in steps of 400 rpm for each load condition. Results of in-cylinder pressure traces, heat release rate, engine power output, brake thermal efficiency and brake specific fuel consumption is presented as engine performance parameters while measurement of exhaust gas temperature, nitric oxide (NO) and carbon mono-oxide (CO) output is reported as emission parameters. It is noted that ED10 has the ability to produce comparable in-cylinder pressure and heat release rate like base diesel fuel. It is also found that ED10 produces slightly less engine power output with higher brake specific fuel consumption (BSFC). In addition, lower exhaust gas temperature and lower NO emission was experienced at all load and engine speed condition for ED10 as compared to diesel fuel. Although diesel engines are not prone to higher CO emission at medium to high engine load, it is found that ED10 suffers from higher CO emission at low load and low engine speed condition. However, at higher engine speed for a particular load, the CO emission reduces significantly. The comprehensive analysis of the experimental results suggests that ED10 has the potential to be considered as a competitive renewable and greener fuel for diesel engine applications.

Zhenbin Chen, Kaimian Li, Jun Liu, Xiaochen Wang, Shengjun Jiang, Chengliang Zhang[8] presented in their technical paper effects of preparation conditions on the stability time of glucose solution emulsified diesel, an orthogonal experimental design L25(5) was used. According to the results of orthogonal experiment, a nonlinear regression model was constructed by response surface methodology (RSM) and optimized by the active set method. The stability time of glucose solution emulsified diesel was about 342 h under the optimal conditions of: 15% glucose aqueous solution, 2% emulsifier, 0.86% cosolvent, 20% glucose in solution and a hydrophilic and lipophilic balance (HLB) value of 5.58. The performance and
emissions of emulsified diesel in a diesel engine was tested and compared with pure diesel. The results showed that brake thermal efficiencies with emulsified diesel improved under partial loads at the speed of 2000 rpm, that NOx and smoke emissions with emulsified fuel decreased except at individual operating conditions, and that HC and CO emissions were different for the two fuels under different conditions.

We Zhang, Zhao Hui Chen, Yinggang Shen, Gequn Shu, Gui sheng Chen, Biao Xu, Wei Zhao[9] presented in their technical paper experiments were conducted on a turbo-charged direct injection diesel engine under the two conditions of 2000 rpm and 180 Nm equivalent power (57% of the original max load at 2000 rpm) as well as 100% load of this speed. The combination of intake oxygen enrichment and water emulsified diesel was used to improve the NO-smoke emissions without serious penalty in brake specific fuel consumption (BSFC). The results showed that when engine load was 180 Nm with the conditions of 0%–20% water emulsion ratio and 21%–21.5% intake oxygen concentration, as well as under the condition of 100% load with 10%–15% water emulsion ratio and 21%–22% intake oxygen concentration, the NO-Smoke emissions were lower than that of original engine and BSFC was not exceeding 5% of the original engine by optimized combination of water emulsion ratio and oxygen concentration. M. Saravanan, A. Anbarasu, B. M. Gnanasekaran [10] presented in their technical paper internal combustion engines generate undesirable emissions during combustion process. The emissions exhausted in to the surroundings pollute the atmosphere and causes several problems. The emissions of concern are: unburnt hydrocarbons, oxides of carbon, and oxides of nitrogen (NOx). Advanced diesel fuel formulations offer significant emission reductions to new and older in-use engines every time the fuel tank is filled. The addition of water to diesel fuel lowers particulate emissions by serving as diluents to the key combustion intermediates that lead to particulate formation. The incorporation of water also reduces NOx emissions by lowering the peak combustion temperatures through high heat of vaporization. When using water blend diesel, the engine fuel system recognizes the liquid as diesel fuel because the water droplet is encapsulated within a diesel fuel. In this experiment, we have used single cylinder four-stroke engine and the water-blend diesel emulsion is used and the diesel emission test, emulsion emission test, and various gases has been analyzed; smoke meter test is also conducted for various rate of loads. The test results from the engine fuelled with water-blend diesel showed reduction in emissions as compared to that of engine fuelled with conventional diesel. The better emissions in the CI engine using water-blend diesel is due to the incorporation of water which reduces NOx emissions by lowering the peak combustion temperatures. Water-blend fuel enhances fuel atomization by micro-explosion. The addition of water to diesel fuel lowers particulate emissions by serving as diluents to the key combustion intermediates that lead to particulate formation. Dr. Eng. Dan Scarpete [11] presented in their technical paper oxides of nitrogen (NOx) and particulate matter (PM) are the main pollutants from diesel engines. Diesel-water emulsion, as alternative fuel, has potential to significantly reduce the formation of NOx and PM in the diesel engine. The emulsion fuel contains water (in the range of 5–15%) and diesel fuel with specific surfactants, to stabilize the system. Reduction of NOx is originated from the reduction of local high temperature due to vaporized water during combustion. The reduction of local high temperature may cause the reduction of reaction rate, which has a possibility of affording a mixing time for better combustion for reducing PM. Micro-explosion, considered as the second atomization, improves fuel combustion and reduces fuel consumption. The heterogeneous results regarding the use of diesel-water emulsion as fuel for diesel engines suggest that experimental work for optimizing the emulsion formulation in terms of water content and internal structure is recommended.

Shyam Prasad H, Joseph Gonsalvis Vijay V. S. [12] presented in their technical paper introduction of water vapours directly or indirectly into the combustion chamber, was one of the effective and most economical tool in reducing oxides of nitrogen (NOx) and particulate matter (PM) in the exhaust gases of diesel engines. Many researchers have developed different systems to introduce water into the combustion chamber like direct water injection, fumigation and water-fuel emulsions. All the different systems have started during the early days of development of aircraft piston engines and since then a significant progress has been made to develop an optimum system to reduce the pollutants from the exhaust gases. This review paper presents both advantages and disadvantages of different water introduction systems achieved by the most recent studies. Also it covers the different features, main findings and theoretical and experimental approaches for water-diesel emulsion and direct water injection for DI diesel engine for further emission reduction.

Angela Chi osa, Dan Scarpete, Raluca-Cristina Buturca [13 ] presented in their technical paper a review on experimental achievements regarding the effects of diesel-water emulsions on burning characteristics and performance parameters of diesel engines; it also highlights peculiarities, advantages and disadvantages of the utilization of water emulsified diesel fuel. The main aspects which are discussed in detail include: ignition delay, micro-explosion, pressure variation, heat release, engine power, thermal efficiency and fuel consumption. Using diesel-water emulsion as fuel for diesel engines is an effective technique in reducing emissions. Agung Sudrajad and Ismail Ali [14] presented in their technical paper of diesel oil-water emulsion fuel (water in-oil type) for direct injection single cylinder diesel engine. The laboratory experimental project is using 10% water mixed with Diesel Oil (DO) and in a few of inorganic surfactant by volume ratio (10% water, 89% diesel oil, 1% surfactant). These components are mixed in mechanical mixer controlled, to produce blending fuel. During the blending process the special surfactant will make oil surrounds the water droplet to prevent the water from separating out of the mixture. The encapsulation of water in oil in micrometer sizing is prevents the water from contacting any metal engine.
parts. The experimental laboratory is conducted with single cylinder diesel engine set-up at 2000 rpm with variable of engine load. Measurement of engine emissions parameters at different load conditions have generally indicated reduce in engine CO, NO and SO2 emission as compared to base diesel oil.

Mohammed Yahaya Khan, Z. A. Abdul Karim, A. Rashid A. Aziz, and Isa M. Tan [15] presented in their technical paper an emulsion droplet suspended on a wire-type thermocouple on a hot plate as the heat source was used to study the evolution of microexplosion phenomenon of emulsions prepared by two different methods. Microexplosion behavior of emulsions produced by a homogenizer and mechanical stirrer with 5, 10, and 20% water by volume was visualized. A high-speed camera synchronized with a data-logging system was used to capture events. The results show that the waiting time, puffing frequency, initial temperature drop, and microexplosion temperature were affected by the size and distribution of the dispersed water droplets. No microexplosion was observed for all of the homogenized emulsions, while all of the mechanically stirred emulsions developed microexplosions.

Patel Sagar H, Rathod Gaurav P And Patel Tushar [16] presented in their technical paper NOx formation was a highly temperature-dependent phenomenon and takes place when the temperature in the combustion chamber exceeds 500 K. Therefore, in order to reduce NOx emissions in the exhaust, it is necessary to keep peak combustion temperatures under control. One simple way of reducing the NOx emission of a diesel engine was by late injection of fuel into the combustion chamber. This technique was effective but increases fuel consumption by 10–15%, which necessitates the use of more effective NOx reduction techniques like water injection in intake manifold. Water injection method was applied to a direct injection (DI) diesel engine to control NOx emissions. This method affects the intake air of an internal combustion engine with cool purified Water, deriving benefits of preventing the formation of excessive oxides of nitrogen and Carbon, affecting more Complete Combustion of hydrocarbon fuels, reducing the latent heat of combustion and increasing the power of combustion. The obtained results are compared with conventional diesel engine in terms of performance and NOx, CO, HC emissions. Various systems have been proposed for conveying water vapor into the combustion chambers of an internal combustion engine to increase the power output therefore and also to provide for better fuel economy.

Omar Badrana, Sadeq Emeishb, Mahmoud Abu-Zaid, Tayseer Abu-Rahma, Mohammad Al-Hasana, Mumin Al-Ragheba [17] presented in their technical paper an experimental investigation was carried out to produce a stable diesel-water emulsion fuel to be used in a diesel engine under different operating conditions. The proper mixing technique and emulsifying agent were used to produce stable emulsions of 10% to 30% water by volume in diesel. The stability of these emulsions ranges from one week up to 4 weeks. The physical properties of stable water-diesel emulsions such as density, viscosity and pour point were observed. The effect of water–diesel concentrations, on the performance of a single cylinder diesel engine in terms of engine speed, torque, brake power output, brake specific fuel consumption, brake thermal efficiency, exhaust gas temperature and emissions such as NOx and particulate matter (PM) were studied. The results showed that the water emulsification has a potential to improve the diesel engine performance and to reduce gas pollutants. Arularasu. S, Appu Raja. S, Thangaraj. M, Annamalai. K [18] presented in their technical paper water-Diesel-Vegetable oil (W-D-V) emulsions are identified as suitable fuel for regular diesel engines. The advantages of an emulsified fuel are reduction in the emissions of nitrogen oxides and particulate matters, which are both health hazards. It has also shown a reduction in fuel consumption and improved combustion efficiency. This review demonstrates the influence of water on the emissions and on the combustion efficiency while using W-D-V emulsified fuel. The review paper also covers similar fuels, such as double emulsions i.e., diesel-in-water-in-diesel emulsions, water-in-diesel micro emulsions, and biodiesel emulsions i.e., water-in-vegetable oil emulsions.

2. REFERENCES:

3. Alain Maiboam, Xavier Tauzia NOx and PM emissions reduction on an automotive HSDI Diesel engine with water-in-diesel emulsion and EGR: An experimental study Fuel, Volume 90, Issue 11, November 2011, Pages 3179-3192
5. Ming Huo, Shenlun Lin, Haiyong Liu, Chia-yen F. Lee Study on the spray and combustion characteristics of water-emulsified diesel Fuel, Volume 123, 1 May 2014, Pages 218-229


