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Performance Characteristics of the Direct Injection Compression Ignition Engine Fuelled by Water in Diesel Emulsion (Wide)

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Abstract

This research is done to investigate the effect of using WIDE (water in diesel emulsion) on the performance characteristics of the direct injection compression engine especially brake torque, brake specific fuel consumption and brake thermal efficiency. The WIDE blends that are used are 0 %, 5 %, 10 % and 15 % WIDE. This experiment was conducted on Yanmar 493cc single cylinder, four stroke direct injection compression ignition engine and at different operating engine speed ranging from 1000 – 1800 rpm at wide open throttle. Brake thermal efficiency and brake torque were found to increases when WIDE is used. This is due to the expansion of water vapor which provides extra force on the highest point of the cylinder that generates higher amount of torque throughout the cycle and volatility different between fuels and water which increases air and fuel mixing at higher engine torque hence improved in brake thermal efficiency. Thus, it can be concluded that certain amount of WIDE has the potential to improve the performance characteristics (such as brake torque, brake specific fuel consumption and brake thermal efficiency) of the direct injection compression ignition engine.

Keywords: Water in Diesel Emulsion (WIDE), Direct Injection, Compression Ignition Engine, Performance Characteristics, Wide Open Throttled (WOT) and Engine Speed.

INTRODUCTION

Diesel engine also known as a compression-ignition engine is an internal combustion engine in which ignition of the fuel that has been injected into the combustion chamber is initiated by the high temperature which a gas achieves when greatly compressed. Since the performance of the diesel is very high, then the fuel consumption utilized is also very high [1-3]. Due to the increase in convectional fuel price, researches on improving the fuel economy of the internal Combustion Engine (ICE) become necessary. Reduction of the fuel consumption became the main target in diesel engine [4-6]. As a viable strategy to reduce this problem, Water in diesel emulsion (WIDE) operation technique is investigated. WIDE operation used the mixture of water and diesel with the aid of chemical called SURFACTANT. This is to improve the fuel economy of the ICE fuelled by WIDE and generate high thermal efficiency [7-9]. There are many published literatures on the implementation of WIDE fuel in a diesel engine. Badran et al., 2010[9] investigated the impact of water in diesel emulsion (WIDE) on brake torque. The results showed that torque is at the lowest when only diesel surfactant mixture is used. Torque value is different when increasing amount water emulsion is used. 30% of water emulsion recorded highest torque value compare with the other types of emulsion mixture which uses 10%, 15%, 20% and 25% of water. This research proved that certain amount of water in the emulsion can improved the performance of compression engine. Singh, 2012 [10] conducted an experimental study on the implementation of water in diesel emulsion [WIDE] in compression ignition engine.The results showed that the highest brake specific fuel consumption value is achieved when 20% of water is used. Besides that, emulsion by using 20% tends to have highest brake thermal efficiency and the amount of CO_2 emission also is the lowest compare with the other percentage of fuel mixture. O. Armas R et al [11] conducted an experimental investigation on the "Characterization of light duty diesel engine pollutant emissions using water emulsified fuel". The results revealed that there was reduction in percentage increase of brake thermal efficiency, while there is reduction in percentage reduction of NO_X, particulate matter (PM), HC and CO emissions. J. Ghojel, D. Honnery and K. Al-khaleefi [12] studied the performance, emissions and heat released characteristics of the direct injection diesel engine operating on diesel oil emulsion. It was concluded that there was 22-26 % increase in specific fuel consumption and 60-90 % reduction in HC emissions and 29-37 % reduction in NO_X emissions as compared with certified diesel fuel (CDF). In addition, E. Alam Fahd, Y, Wenming, P, Lee, S. Chou and C.Yap [13] conducted the experimental investigation on the "Performance and Emission Characteristics of the direct injection diesel engine by water emulsion diesel under varying load condition". The results showed there was increase in Brake thermal efficiency with speed and reduction in NO_X emissions. Up till now, information is still lacking on the comparative advantage of the WIDE and convectional diesel implementation in compression ignition engine. Therefore, this study will focus on comparing the performance characteristics of the of WIDE using various fractions (5%, 10% and 15%) and convectional diesel (0%) in direct injection compression ignition engine and clarify the engine behavior under this operating conditions.

COMBUSTION EQUATION REPRESENTING WIDE

The combustion equation representing wide operation where the air-fuel ratio utilizes in this experiment was calculated is given below:

$$C_{12}H_{23}+Z\left(O_2+3.67N_2\right)\rightarrow {}^{A}CO_2+{}^{B}H_2O+{}^{C}O_2\times {}^{D}N_2$$

- 0 % of excess air which no excess oxygen exists
- 100% theoretical air

$$C_{12}H_{23}+17.75\left(O_2+3.67N_2\right)\rightarrow 12CO_2+11.5H_2O\times 66.74N_2 \quad (2)$$

$$staichiometry\ air:fuel\ ratio=\frac{(mass\ of\ air)}{(mass\ of\ fuel)} \quad (3)$$

EXPERIMENTAL PROCEDURES

Table 1 shows the specification of the test engine which is used for this research. A four stroke single cylinder engine was used to investigate the effect of using water in diesel emulsion (WIDE) with the aid of surfactant on Performance characteristics of the direct injection compression ignition engine. Figure 2 below show the schematic diagram of the experimental set up.

Table 1: Test engine specification

Engine Properties	
Engine type	Yanmar single cylinder, four stroke compression ignition engine
Displacement Volume	493 cm^3
Compression Ratio	18:1
Cooling System	Water Cooled (Radiator)
Max Power Output	8.2 kw at 2500 rpm

The supply system consists of Water in Diesel Emulsion (WIDE) fuel line, pressure gauge and flow meters. The experiment begins after the engine had been let running for a period of time to let the oil and coolant temperature become stable. WIDE fuel was injected into the engine cylinder. An Electronic Control Unit (ECU) was used to control all the engine operating parameters such as throttle position, stoichiometric air-fuel ratio, engine speed and various others. A dynamometer was used to collect the performance characteristics data. The research was carried out at wide open throttle (WOT), late injection timing and various engine speed of 1000, 1200, 1400, 1600 and 1800 r/mins, were being utilized.The experiment was conducted by using different type of WIDE at full load. The cooling system is used to reduce the temperature of lubricant and cylinder by connecting to a cooling water supply. Fuel feeding system is installed in order to supply the fuel to the engine. The properties of WIDE fuel used are shown in Table 2.

Table 2: Properties of Emulsified Fuel

Type Of Fuel	Density (kg/m^3)	Calorific Value (kj/kg)
0 % WIDE	832	42500
5 % WIDE	852.5	41500
10 % WIDE	852.5	40000
15 % WIDE	852.2	39200

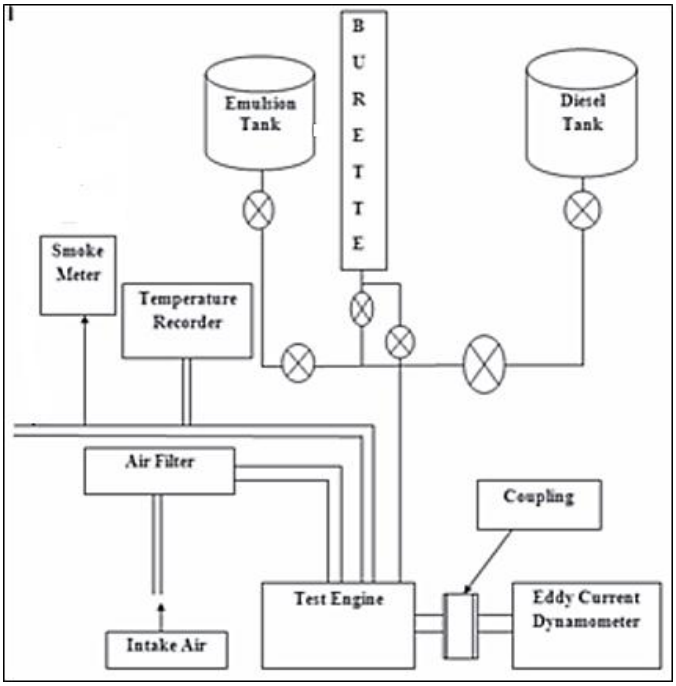

Figure 1: Schematic diagram of the experimental setup

RESULTS AND DISCUSSION

Performance Characteristics

The results of the performance characteristics of the direct injection compression ignition fuelled by different fractions of WIDE and convectional diesel are shown below. Different engine speeds utilized are 1000, 1200, 1400 and 1600 rpm. Direct Injection compression ignition engine under the influenced of WIDE and convectional diesel fuel were analyzed for its performance characteristics such as **Brake torque**, **Brake specific fuel consumption (BSFC)**, and **Brake thermal efficiency.**

Brake Torque

Figure 2 shows the relationship between the brake torque and engine speed at various WIDE respectively. As the engine speed increases, the torque for all type of fuel blend increases. This is because increase in engine speed increases the turbulence within the engine cylinder consequent upon this, brake torque will increase. Comparing the brake torque at various fuel blends, 5% WIDE has the highest amount of brake torque due to the expansion of water vapor which provide extra force on the highest point of the cylinder that generates higher amount of torque throughout the cycle while 15 % WIDE has the lowest brake torque. This is because higher reduction in diesel fuel is occurring at 15 % WIDE and the higher heat that is necessary for water evaporation process. In addition, examine the data point at 5 % WIDE for 1000 rpm and 1800 rpm respectively. It revealed that brake torque for 1000 rpm is 7.4 Nm while at 1800 rpm is 13 Nm. This show about **43%** increment in brake torque at that operation condition. While the brake torque for 15 % WIDE for the same operating condition under consideration are 6.5 Nm and 12.6 Nm respectively. This represents approximately

48% increment in brake torque at that operating condition. From the foregoing, it is plausible to say that certain amount of WIDE has good impact on increasing performance characteristics of the direct injection compression engine. Good agreement is achieved between these experimental results and [10].

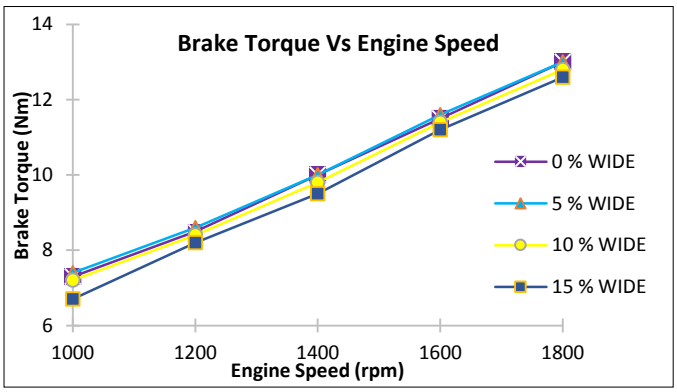

Figure 2: Brake torque vs engine speed at various (WIDE)

Brake Specific Fuel Consumption (BSFC)

The variations of brake specific fuel consumption with engine speed fuelled by different types of WIDE blends are displayed in Figure 3. Based on the graph, the BSFC for all type of WIDE blends decrease as the engine speed increase. This is due to the efficient mixing of air and fuel at high engine speed thus enhanced the fuel combustion. Moreover, 15 % WIDE record the highest BSFC. This is because when the percentage of water increase in the emulsion, the equal amount of water is displaced by an amount of diesel which triggered in lower heating values therefore increased the consumption of fuel at same power output while 0 % WIDE has the lowest BSFC among all of the tested fuel due to its higher heating value and shorter ignition delay that are required for fuel burning process. Also, considered the data point at 15 % WIDE for 1000 rpm and 1800 rpm respectively. It recorded that BSFC for 1000 rpm is 0.73 kg/Kw.hr while for 1800 rpm is 0.22 kg/Kw.hr. This shows about **70 %** reductions in BSFC when engine speed is increases. While BSFC for 0 % WIDE for the same operating condition under consideration are 0.65 kg/Kw.hr and 0.20 kg/Kw.hr respectively. This measure about **the same decrement in BSFC as in before**. Thus we can conclude that WIDE is a good strategy to obtain a significant improvement in fuel consumption. This WIDE will improve the BSFC for the following reasons: (i) The expansion stroke work for a given expansion ratio is increase as a result of the change in thermodynamic properties of the burned gases (ii) Reduced heat loss to the walls because the burned gas temperature is decreased significantly (iii) Reduction in the degree of dissociation in the high-temperature burned gases which allows more of the fuel's chemical energy to be converted to sensible energy near TDC. The experimental results obtained here is coherent with what is obtained in [9, 15].

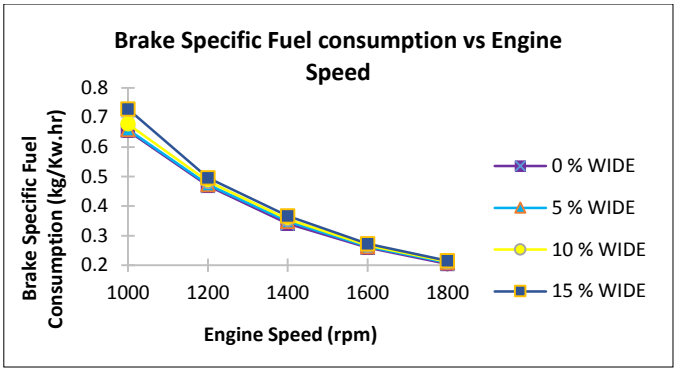

Figure 3: Variation of BSFC with engine speed for different type of WIDE

Brake Thermal Efficiency (BTE)

The influences of using different type of WIDE on brake thermal efficiency are shown on Figure 4. The graph show an increment of brake thermal efficiency for all type of emulsion when the engine speed increases. This might largely be due to the fact that, as the engine speed increases, the net work done will be relatively higher (increase in expansion work and reduction in compression works) as result of expansion of water vapor. The emulsions with 15 % WIDE showed the highest brake thermal efficiency due to the volatility different between fuels and water which enhances the air and fuel mixing at higher engine torque hence improved in BTE. While 0 % WIDE has the lowest brake thermal efficiency. This is resulting from the higher calorific value and boiling point of the diesel which deteriorates the evaporation process and prevent micro explosion that can increase combustion efficiency. Comparing the data points at 15 % WIDE with that at 0% WIDE at engine speed of 1000 rpm and 1800 rpm respectively. The data show that the BTE for 1000 rpm is 13.55 % while for 1800 rpm is 43.34 %. This represents approximately **70%** increment in BTE. While for 0 % WIDE and for the same operating condition under consideration the BTE respectively are 12.94 % and 41.18 %. This measure about **the same increment in BTE as in before**. Similar result has been obtained in the literature which showed that maximum brake thermal efficiency occurs when 15 % WIDE are used and this is in agreement with [9, 10 and 14].

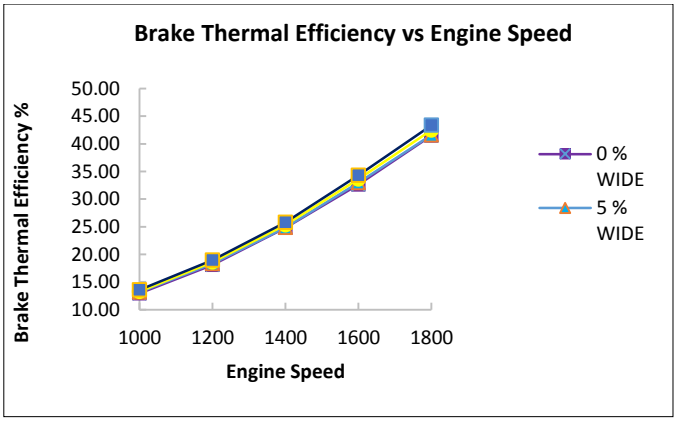

Figure 4 : Variation of Brake Thermal Efficiency versus Engine Speed at different WIDE.

CONCLUSIONS

An experimental study has been performed to study the performance characteristics of the direct injection compression ignition engine fuelled by Water in Diesel Emulsion (WIDE) under various operating condition of the engine such as (1000 – 1800 rpm), Wide Open Throttle (WOT) and stoichiometry condition. The main results are summarized below:

- **Brake Torque**

  5% WIDE showed the highest value of brake torque due to the expansion of water vapor which provides extra force on the highest point of the cylinder that generates higher amount of torque. On the other half, 15 % WIDE water has the lowest amount of torque. This is because higher reduction in diesel fuel is occurring at 15 % WIDE and higher heat that is necessary for water evaporation process. It is show that from the figure that 5% WIDE has good impact on increasing performance characteristics especially brake torque.

- **Brake Specific Fuel Consumption**

  15 % WIDE record the highest BSFC. This is because when the percentage of water increase in the emulsion, the equal amount of water is displaced by an amount of diesel which triggered in lower heating values therefore increased the consumption of fuel at same power output. This show that higher fuel emulsions will have higher brake specific fuel consumption compared with engine that use standard fuel.

- **Brake Thermal Efficiency**

  Highest brake thermal efficiency occurs at 15 % WIDE. This is due to the volatility different between fuels and water which increases air and fuel mixing at higher engine torque hence improved in BTE.

- Based on the result obtained, it can be concluded that emulsified fuel has a potential to improve the performance characteristics of direct injection compression ignition engine and the maximum amount of water that is good for WIDE operation in direct injection compression ignition engine is 5 % WIDE.

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