Evaluation of DMF as an efficient fuel for direct injection spark ignition (DISI) engine

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ABSTRACT

Alternative fuels are very important when considering the power requirements in the modern world today. Biofuels were introduced to satisfy these requirements which will play a major role in future. 2,5-dimethylfuran known as DMF was developed as a new biofuel and it has several advantages over others as a gasoline alternative biofuel. But when we talking about automobiles, engine modification are needed to make use of biofuels. Our research is about evaluation of DMF as an efficient fuel for direct injection spark ignition engine.

A mounted four stroke direct injection spark ignition engine (DISI) with 100CC capacity, was used to perform the research. Also supporting instruments were required with engine to take the measurements which were needed to check the performance through analysing results. 'Single cylinder multi fuel VCR engine test rig'; a special multi fuel testing system was used to get testing results. DMF, ethanol with different percentages by volume and pure petrol samples were tested under different engine conditions.

When analysing results, a mathematical model was developed with considering various engine specifications. Brake power, indicated power, friction power, and heat losses were considered. Also, specific fuel consumption, mechanical efficiency, brake thermal efficiency, indicated thermal efficiency and volumetric efficiency were calculated because these are the main facts required to check the engine performance. Using our results various graphs are plotted between different parameters of engine and fuels.

KEYWORDS: DMF, direct injection spark ignition engine, biofuels, ethanol, petrol

INTRODUCTION

When finding alternatives to the fossil fuels, biomass fuels have some important qualities as candidates to the alternatives of fossil fuels. There are some important requirements which a biofuel should satisfy if it is to be used as an alternative to fossil fuels. But none of the biofuels satisfy these qualities whereas we have to find the best biofuel which can be used in engines without the need of major modifications. Bio-ethanol satisfies some of the requirements but none of the biofuels does not satisfy all the requirements. Bio-ethanol is called as the most successful gasoline-alternative. But bulk production of bio-ethanol influences the environmental equilibrium and the food production.

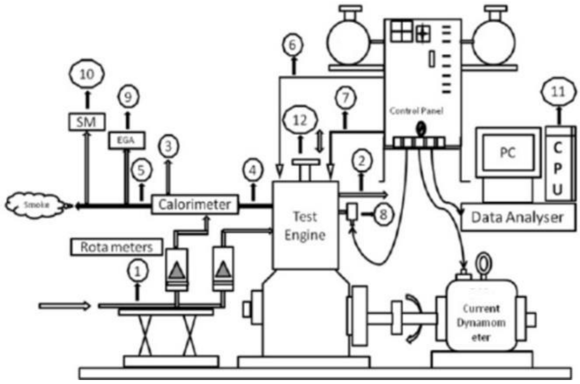
2,5-dimethylfuran known as DMF was developed as a new biofuel and it has several advantages over ethanol as a gasoline alternative biofuel. Therefore, scientists and research communities showed an interest in use of DMF as a fuel in engines and power generation. Some important parameters like energy density, lower heating value, water solubility, boiling point, environmental impacts are found to be more positive in use of DMF rather than other biofuels, most importantly rather than bio-ethanol.

DMF was used in minor purposes in the food production industry and for improving octane number of gasolines. After that some methods were developed to produce it with a higher yield and low energy consumption. There-fore scientists focused on using it as an alternative to gasoline. Firstly, the research was initiated to investigate DMFs combustion performance and emissions as an alternative fuel in modern automotive engines at Birmingham University in the UK. It covers the aspects of internal combustion engine includes the spray characteristics, laminar burning velocity, engine performance, regulated and unregulated engine emissions and some novel methods for optimizing the use of biofuels.

Spray characteristics of a fuel are very much important when considering about the engine performance and the emissions. Main spray characteristics with time, which directly affect the fuel-air mixture generation and consequently, combustion behavior including the spray cone angle and penetration length were measured using optical methods, utilizing shadowgraph and high-speed cameras. The laminar burning velocity is also an important parameter when considering the performance of an engine. It affects the burn rate of the fuel. Engine performance is evaluated by the parameters like optimum spark timing, fuel economy or exhaust temperature. It is also important to find out the regulated engine-out emissions of a burning of a fuel in an engine.

Biofuels are an important alternative to reduce CO_2 emissions, improve fuel security and bring other environmental and economic benefits. Today ethanol is the only large-scale biofuel which is used for spark-ignition engines. Bio-ethanol is called as the most successful gasoline-alternative. But bulk production of bio-ethanol influences the environmental equilibrium and the food production. Also, there are some limitations of bio-ethanol such as low energy density, high volatility, and high energy consumption. So, scientists' trend to

introduce new sources of biofuels that might become available in the near future.



Recent biological and chemical improvements to the conversion of biomass-derived carbohydrates have produced high yields of liquid 2,5-dimethylfuran (DMF).

EXPERIMENTAL PROCEDURE

Materials

1. DMF 99 wt%
2. Ethanol 95 wt%
3. Petrol

Methodology

•Following samples were prepared

1. 500 ml of 10% DMF by volume
2. 500 ml of 20% DMF by volume
3. 300 ml of 10% Ethanol
4. 500 ml of petrol

•The lambda meter was adjusted for 8 (the air-fuel ratio for each fuel.) (Gasoline, Gasoline+10%Ethanol, Dimethyl furan (DMF)).

•Using the air supplier supply the constant air flow rate and engine must be covered using casing.

•The engine was set at 1500 rpm constantly

•Selected the fuel and the measurement were taken initially without load

•Using thermometers, the air input and output temperatures, exhaust gas temperature and ambient temperature were measured

•The load was then changed to 2.5 kg, 5kg, and 7.5 kg respectively

Brake Power

Break power is defined as the power developed at the output shaft which in a practical sense is the most vital output of an engine. The break power was calculated in the equations mentioned below

$$Brake\ power = \frac{F \times R \times 2N\pi}{60} = W \times N\left(\frac{2\pi R}{60} \times 10^3\right) = \frac{W \times N}{\frac{1}{\left(\frac{2\pi R}{60} \times 10^3\right)}}$$

$W - load$

$N - speed(RPM)$

$Indicated\ power$

$$Indicated\ power = \frac{kP_m LAn}{60}\,(KW)$$

$K = number\ of\ cylinders$

$L = length\ of\ stroke$

$A = cross\ section\ area\ of\ piston = \frac{\pi \times d^2}{4}$

$P_{mean} = mean\ effective\ pressure\ (kPa)$

$n = number\ of\ strokes\ per\ minute$

$n = N(2\ strokes)$

$n = \frac{N}{2}(4\ strokes)$

Brake thermal efficiency

Break thermal efficiency is vital in a fuel/engine as this is a relationship between the power input to the engine and the break power which is obtained after considering frictional loses and other losses.

$Brake\ thermal\ effciency = overall\ efficiency$

$$\eta_{Brake\ thermal\ effciency} = \frac{brake\ power}{rate\ of\ heat\ input\ by\ fuel}$$

$$\eta_{Brake\ thermal\ effciency} = \frac{\left(\frac{W \times N}{K}\right)}{\dot{m}_{fuel} \times H} \times 100\%$$

Volumetric effiency

Volumetric efficiency is an indication of the ability to fill the engine with air. With increasing volumetric efficiency, the torque and power is increased. However, this is not a direct indication of the efficiency of the engine or the fuel.

$$volumetric\ efficiency = \frac{volume\ inhaled}{swept\ volume}$$

$$volume\ inhaled = \frac{4.193}{35.22} \times d^2 \times \sqrt{\frac{h \times T}{H}} \left(\frac{m^3}{min}\right)$$

$$swept\ volume = 4 \times \frac{\pi}{4} \times D^2 \times L \times \frac{N}{2}\ (m^3/min)$$

Knocking Properties

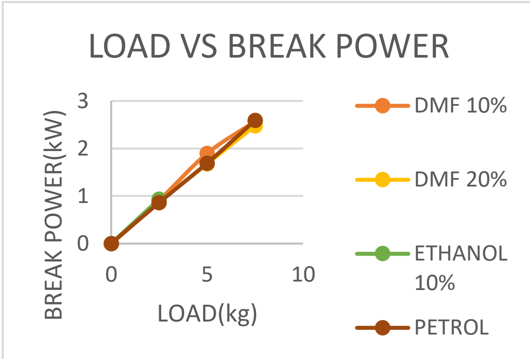
In single cylinder four stroke constant speed and air cooled direct engine that has above characteristics, which depends on the average pressure, heat release rate and temperature of cylinder in the engine.

In terms of performance of engine ignition delay is most important parameter which is evaluated based on dynamic pressure built up in the cylinder. It is defined as the time from, when the fuel injection starts to the combustion. Many parameters affected the ignition delay time when considering about the pressure and temperature of the combustion chamber (DMF gasoline mixture) where the pressure and temperature increased. Since, the mixture ignition delay is decreased.

RESULTS AND DISCUSSION

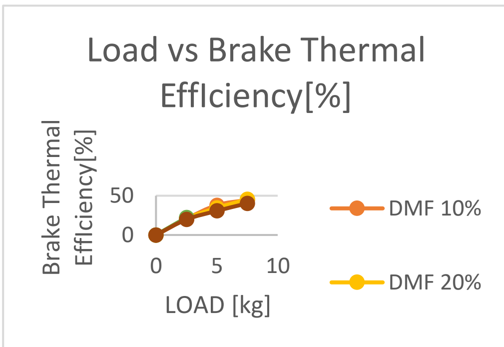
Break Power

The break power was plotted for the



prepared samples against different loads.

From the above graph it can be determined that break power plots fall in the same region and do not show any deviation from each other. The DMF 10% sample can be observed to give higher break power under smaller loads. But under heavy loads the break power of the engine is observed to be increasing in petrol. The break power of DMF 20% sample can be observed to be moderate.



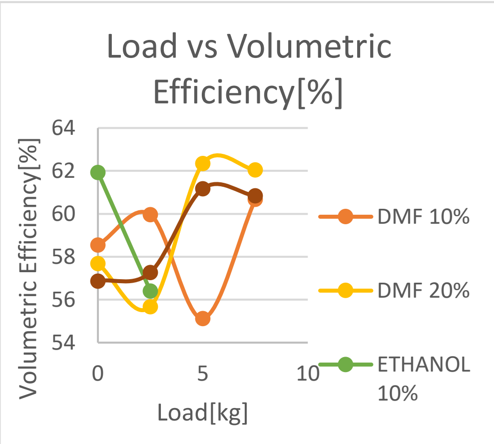
Brake thermal efficiency

It can be determined from this graph that the break thermal efficiency is higher in DMF 10% and DMF 20% than petrol.

The break thermal efficiency can be observed to be increased further in DMF 20% with increasing load.

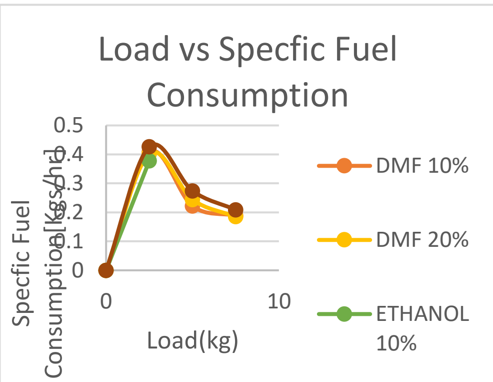
Volumetric effiency

It can be observed that there is no pattern followed by any of the samples. But DMF 20% sample shows increase in volumetric efficiency with increasing load.



Specific fuel consumption

Specific fuel consumption is defined as the amount of fuel required to produce a unit of power.



Specific fuel consumption decreases with increasing load. However, it can be observed that DMF 10%, and DMF 20% are somewhat below the petrol line indicating that less units of fuel are required to give the same output power.

CONCLUSION

When ignition delay or knocking properties are compared DMF did not show heavy knocking properties as expected. This is a huge advantage in mass replacement of petrol as no serious alterations will have to be done to the existing petrol engines when they are replaced with DMF.

When analysing the results for break power, break thermal efficiency, volumetric efficiency and specific fuel consumption DMF 10% and DMF 20% are ahead of petrol. But the true potential of DMF cannot be identified operating with calibrations for a petrol engine as was done in the experiment. Future studies have to be done to determine the optimum air/fuel ratio, fuel flow rates for optimum combustion in the engine and etc.

But the replacement of petrol with DMF is possible for existing vehicles and this only will make the performance of the existing vehicles better.

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The tests were done by the Single Cylinder Multi Fuel VCR Engine Test Rig which mainly operates with diesel or petrol. For a complete understanding of the potential of DMF as a petrol substitute has to be carried out in an engine specifically designed for DMF. However, it was concluded that in most of the results obtained, DMF showed critical positive advancements over petrol.

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