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Experimental investigation of using methanol-diesel blended fuels in diesel engine

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Abstract

A comprehensive study on the methanol as an alternative fuel has been carried out. A four stroke four cylinder diesel engine was adopted to study engine power, torque, break specific fuel consumption, break thermal efficiency and exhaust temperature with the fuel of fraction methanol in diesel. In this study, the diesel engine was tested using methanol blended with diesel at certain mixing ratio of 10:90, 20:80 and 30:70 of methanol to diesel respectively. The performance of the engine using blended fuel compared to the performance of engine with diesel fuel. Experimental results showed that the output power and torque for diesel fuel is lower compared to methanol-diesel blended fuel at any ratio. The best mixing ratio that produced the lowest exhaust temperature was at 10% of Methanol in 90% of Diesel fuel. The exhaust temperature for diesel fuel was higher compared to any mixing of the blended fuel. The brake specific fuel consumption for the three mixing ratios was not varying significantly but the lowest was for 30% Methanol and 70% Diesel. The specific fuel consumption for diesel fuel was much lower compared to any mixing ratio. It was noticed that brake thermal efficiency was thus improved in almost all operation conditions with the methanol and diesel blended fuels.

Keywords: Methanol, CI engine, Engine performance, Methanol-diesel blends.

1. Introduction

A lot of researches have been done on the prospect of methanol as an alternative fuel. Methanol, CH_3OH, is the simplest of alcohol and originally produced by the destructive distillation of wood. Today it is produced in very large quantities from natural gas by the reformation of the gas into carbon monoxide and hydrogen followed by passing these gases over a suitable catalyst under appropriate conditions of pressure and temperature [1]. Historically, alcohols have been added to the engine intake air (fumigation) since they do not mix well with diesel [2, 3]. Few tests have been conducted using fumigation method. The results are very impressive. The thermal efficiency for fumigated diesel has improved 30% in a direct injection engine at certain combination of alcohol and diesel fuel ratios and overall equivalent ratio [4]. It has been observed that engines running on methanol alone were prone to pre-ignition, in spite of high octane rating of the fuel. Due to the cost factor and other technical problems, the use of methanol as fuel was confined mainly to the racing arena. For internal combustion engines, alcohols, methanol and ethanol, are tested and demonstrated in the world [5]. E10 (10% ethanol in volume and 90% gasoline in volume) fuel and M15 (15% methanol in volume and 85% gasoline in volume) is used [6]. Table 1 compares a parts of the fuel properties, from which the advantages can be summarized as following [7, 8 and 9]:

(1) Emissions from methanol cars are low in reactive hydrocarbons (which form smog) and in toxic compounds. Methanol-fuelled trucks and buses emit almost no particulate matter (which cause smoke, and can also be carcinogenic), and much less nitrogen oxides than their diesel-fuelled counterparts.

(2) Methanol can be manufactured from a variety of carbon-based feedstock such as natural gas, coal, and biomass (e.g., wood). Use of methanol would diversify the country's fuel supply and reduce its dependence on imported petroleum.

(3) Methanol is much less flammable than gasoline and results in less severe fires when it does ignite.

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(4) Methanol has a higher laminar flame propagation speed, which may make combustion process finish earlier and thus improve engine thermal efficiency [9].

(5) Methanol is a high-octane fuel that offers excellent acceleration and vehicle power. Though the latent heat of methanol is higher, measures are not necessary for the mixture preparing due to lower fraction, while it may increase engine volumetric efficiency and thus increase engine power [6]. With economies of scale, methanol could be produced, distributed, and sold to consumers at prices competitive with gasoline. This paper will carry out further study on the effects of methanol, and its fraction on CI engine performance.

2. Experimental study

A four stroke four cylinder diesel engine is used for the testing. The specification of the engine is mentioned in Table 2. Several kinds of fuel blends were prepared for the different purpose of engine test, containing 10%, 20% and 30% of methanol in volume. For the testing, the calorific value of diesel is assumed to be 45.0 MJ/kg and the calorific value for methanol is taken to be 23.8 MJ/kg. The specific gravity for diesel and methanol is 0.84 and 0.79 respectively. Calculated values for Lower Calorific Value are mentioned in Table 3.

Table 1. Comparison of fuel properties

Property	Methanol	Ethanol	Petrol	Diesel
Chemical Formula	CH_3OH	C_2H_5OH	C-C mix	C-C mix
Molecular Weight	32	46	-	-
Boiling Point (^oC)	64.5	78	40-190	170-340
Density at 20^oC (kg/l)	0.792	0.789	0.74	0.84
Stoic. Air/Fuel Ratio	6.4:1	9:1	14.7:1	-
Cetane No	3	8	10	50-55
Octane No	92	90	80-90	-
Calorific Value (kJ/kg)	23800	-	43600	44500
Flash Point (^oC)	11	-	-43	52
Auto IgnitionTemp (^oC)	464	360	220-260	180-240

Table 2. Engine Specifications

Model	Klockner- Humboldt-Deutz AG
Type	F4L 913, four stroke diesel
No. of cylinder	4
Bore x stroke (mm)	102 X 125
Displacement (Lit)	4.086
Rated Speed , Rpm (max)	2800
Compression ratio	15.5:1
Firing Order	1-3-4-2
Operating Fuel Injection Pressure (Bar)	175
Compression Pressure (Bar)	24 - 28

3. Results and discussion

3.1. Torque

The graph (Fig. 1) for torque shows the decreasing curve as the engine speed increases. However, for diesel, the curve is quite constant with a small gap between maximum and minimum value. The starting torque is always high at low engine speed and keeps on decreasing as the engine speed increased. For methanol-diesel blended fuels, torque was higher than diesel fuel.

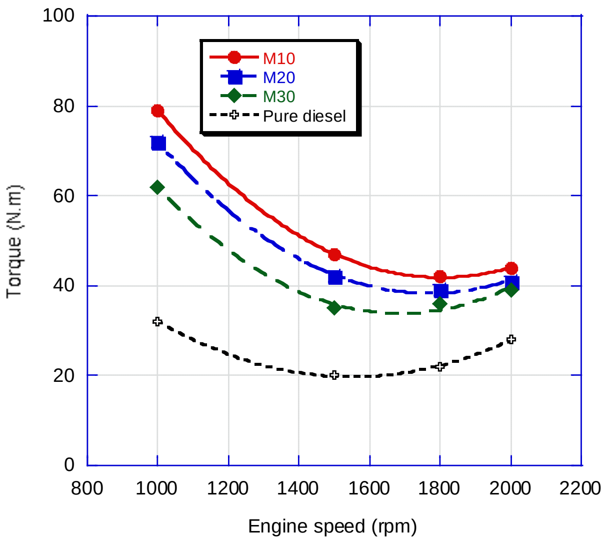

Fig. 1. Engine torque vs. engine speed for different methanol-diesel blended fuels at full load

3.2. Input power

Fig. 2 shows the effect of various fuels on engine input power. When the methanol content in the blend fuel is increased, the engine input power is decreased for all engine speeds, but it was noticed that input power for methanol and diesel blends are higher than diesel fuel. Input power is the power produces by the amount of fuel injected to the engine. It is calculated based on the flow-rate and lower calorific value of the fuel. Actually, the input power can be influenced by the level of combustion whether it is complete or incomplete. Of course, it is almost impossible to get the complete combustion in IC engine. But the more complete combustion, the more input power can be obtained. The calculated input power is the theoretical value and the maximum possible power can be obtained from the fuel if it is burned completely. There will be unburned fuel at every stroke as a result of incomplete combustion. According to a hypothesis, it is good for the cycle. Once the misfire occurred, a small amount of unburned methanol and air trapped in the clearance volume at the end of the exhaust stroke. This would become diluted during the following induction stroke, resulting in a very lean methanol-air mixture existing during the following compression stroke. At the end of compression just prior to the next fuel injection, there would be present in the cylinder a small percentage of fully vaporized methanols at an elevated temperature. In this vapour, that would not normally present, which form a centre of ignition of the next charge of fuel [12]. It shows that lean combustion can be achieved by blended fuel when a lot of fuel injected to the cylinder. The incomplete combustion in the prior stroke will lead the leaner combustion in the next stroke. This phenomenon can be performed by introducing a small quantity of methanol at inlet air. The graph (Fig. 2) shows that the input power of blended fuel for any mixing ratio is much higher compare to diesel. From the observation, the exhaust emission during the testing using blended fuel produced a lot of smoke however for diesel, the emission is quite considerable. It shows that the combustion for diesel is better than blended fuel. Of course, it is because the engine is designated for diesel. The brake power for diesel is much lower than the blended fuel.

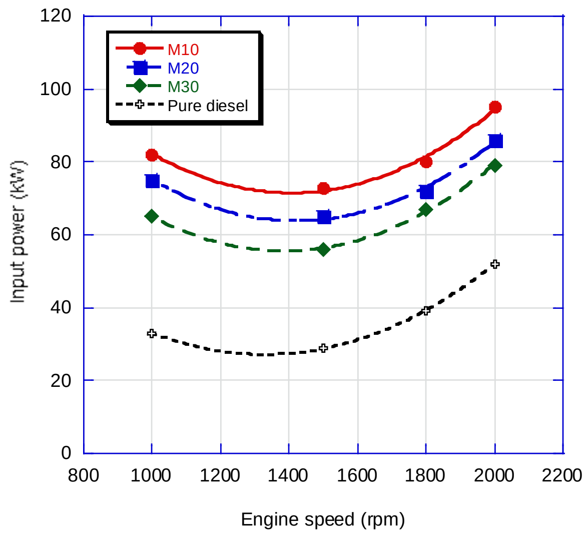

Fig. 2. Input power vs. engine speed for different methanol-diesel blended fuels at full load

3.3. Output power

The output power of blended fuel and methanol varies significantly. The output power for diesel is lower compared to blended fuel at any ratio (Fig 3).

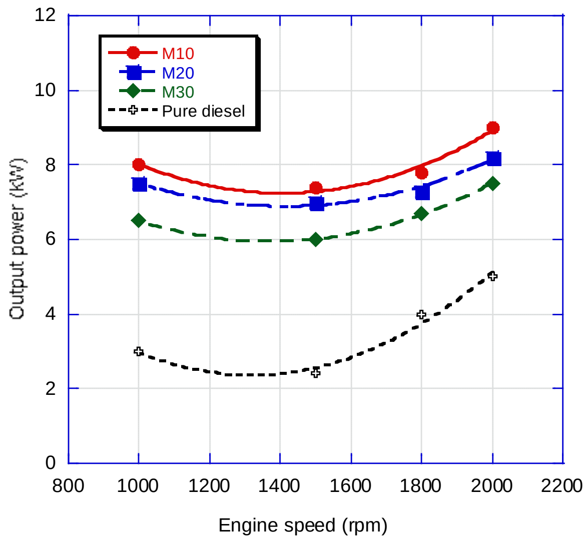

Fig. 3. Output power vs. engine speed for different methanol-diesel blended fuels at full load

The efficiency of the engine is about 10 % which is very low for a compression ignition engine. Basically, the efficiency of compression ignition engine is high due to its compression ratio. In the testing, the input power cannot be determine accurately because the brake power is fixed at certain amount. The power output of diesel engine increases with the amount of fuel injected but is usually limited by the increased smoke emissions as stoichiometric mixture ratios are approached.

3.4. Brake specific fuel consumption

The specific fuel consumption for blended fuel is not good for part load and full load compared to diesel. A significant difference between blended fuel and diesel fuel is observed during the testing. The specific fuel consumption for the three mixing ratios does not vary significantly but the lowest is for 30% Methanol and 70% Diesel (Fig. 4). The specific fuel consumption for diesel is much lower compared to any mixing ratio. The reason is the lower calorific values for both type of fuel. The lower calorific value for blended fuel is lower than diesel. In order to get the same amount of input power, the amount of blended fuel must be greater. At low engine speeds, the brake specific fuel consumption increased leading to the conclusion that emulsions have limited use [12]. It is possible to increase the performance of the blended fuel by adding some additives to the fuel. The additive may be other chemical solution such as lead to increase the octane rating of blended fuel.

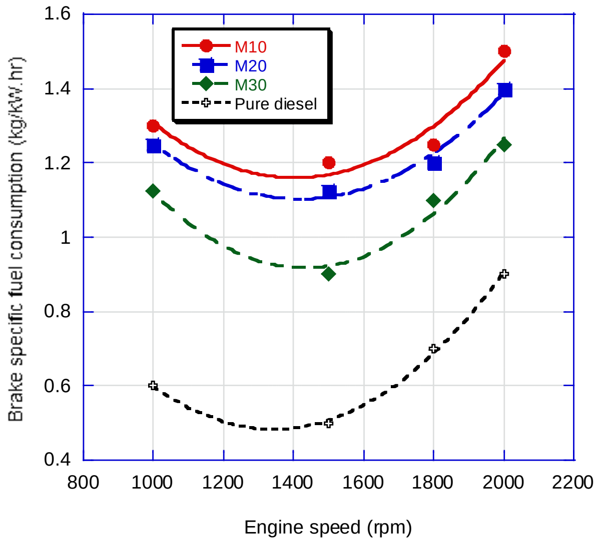

Fig. 4. Brake specific fuel consumption vs. engine speed for different methanol-diesel blended fuels at full load

3.5. Brake thermal efficiency

Brake thermal efficiency is the percentage ratio of the output and the input. In this testing, the output is set to a certain load and the input can be calculated based on the amount of fuel used and time taken.

With decreasing of input power, the efficiency of the engine increases. The engine efficiency is proportional combustion efficiency. Improving the other factor such as input power, specific fuel consumption and exhaust temperature will lead to increase in brake thermal efficiency.

3.6. Exhaust gas temperature

The fig. 5 shows the exhaust temperature for full load operation. At all range of engine speed, the best mixing ratio that produce the lowest exhaust temperature is at 10% Methanol and 90% Diesel. The exhaust temperature is higher compared to any mixing of the blended fuel. The exhaust temperature is related to the production of NOx which is poisonous and harm to environment. High exhaust temperature means that high emission of NOx. In this case, it is proper to use the blended fuel to decrease the emission of the NOx. The lower calorific value for methanol is much lower compared to diesel which are 23.8 MJ/kg and 44.5 MJ/kg for methanol and diesel respectively. Since the engine is designated for diesel fuel, the combustion for diesel is more complete. In fact, the combustion for both types of fuel is in the lean side. However, the combustion for diesel is leaner than blended fuel. Lean combustion produces a lot of heat and thus increases the exhaust temperature.

The lower exhaust temperature for blended fuel implies that the lower production of NO_x. The composition of methanol itself contains oxygen component the can assist during the combustion. The greater the amount of fuel injected to the combustion chamber means that more oxygen would be required for complete combustion; the blended fuel will not face any severe difficulties to reach complete combustion. In term of emission, it is better to use the blended fuel for the engine. Methanol is more difficult fuel to operate in a diesel engine than in a spark ignition engine and the main impetus to use it is not economic but strategic and environmental [10]. The production of NO_x is proportional to combustion efficiency. The better the combustion efficiency, the higher the value of exhausts temperature and thus increases the level of NO_x production. Methanol fuelled vehicles normally shows a lower content of CO and NO_x in their exhaust however, NO_x must be watched in vehicles that have high thermal efficiency [11].

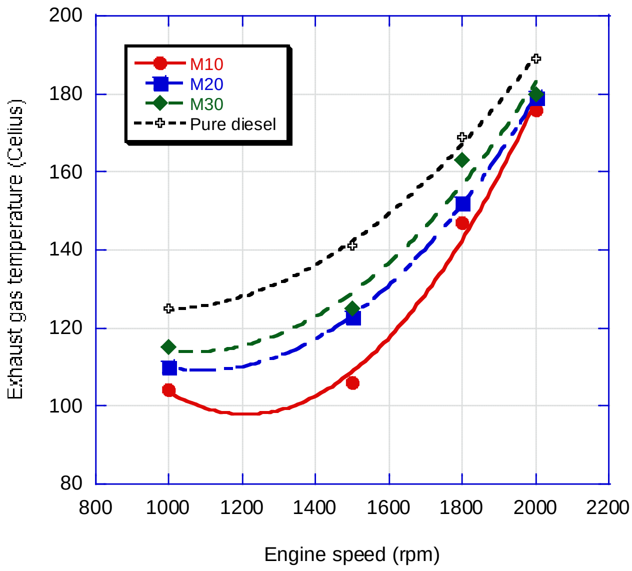

Figure 5: Exhaust gas temperature vs. engine speed for different methanol-diesel blended fuels at full load

4. Conclusion

From this study, it can be concluded that methanol/diesel blend can be used in diesel engines. Experimental results showed that the output power and torque for diesel fuel is lower compared to methanol-diesel blended fuel at any ratio, the exhaust temperature for diesel fuel was higher compared to any mixing of the blended fuel, the brake specific fuel consumption for the three mixing ratios was not varying significantly but the lowest was for 30% Methanol and 70% Diesel but specific fuel consumption for diesel fuel was much lower compared to any mixing ratio.

Table 3. Calculated values for Lower Calorific Value (LCV)

Diesel	Methanol	CO_2	H_2O	O_2	Hf	Molecular	LCV
a	b	d	e	c	(kJ/kMol)	Weight	(MJ/kg)
1	0	16	17	16	-9957260	226	-44.06
0.9	0.1	14.5	15.5	14.45	-9073131	206.6	-43.92
0.8	0.2	13	14	12.9	-8189002	187.2	-43.74
0.7	0.3	11.5	12.5	11.35	-7304873	167.8	-43.53
0.6	0.4	10	11	9.8	-6420744	148.4	-43.27
0.5	0.5	8.5	9.5	8.25	-5536615	129	-42.92
0.4	0.6	7	8	6.7	-4652486	109.6	-42.45
0.3	0.7	5.5	6.5	5.15	-3768357	90.2	-41.78
0.2	0.8	4	5	3.6	-2884228	70.8	-40.74
0.1	0.9	2.5	3.5	2.05	-2000099	51.4	-38.91

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