International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-8 Issue-5, June 2019

Effect of Dual Fuel Injection on the Emission Characteristics of a Single Cylinder CI Engine using Alcohol Diesel Blends with Preheated Air

S.P.M.Vignesh, S.Srihari, S.Thirumalini

Abstract: ***In this study, experimental investigation is carried out on the performance and emission characteristics of diesel-methanol fuel blends with pilot injection. A single cylinder, four stroke, air cooled diesel engine is used for the study. The various methanol blend percentage by volume used in the engine are 5% and 10% in diesel. The engine is maintained at a constant speed of 2300 rpm with variable load conditions. Performance and emission parameters are observed on the engine using pilot injection and main injection strategy by preheating the intake air at the intake manifold. The methanol-diesel fuel blend is prepared by using mechanical stirring technique. The performance and emission characteristics are observed and compared with the base line diesel. It is observed that the brake thermal efficiency is increased for both the blends at higher load conditions when 10% pilot injection is used. A reduction in BSFC is also noticed for M5 and M10 blends. The emission parameters such as smoke, CO and HC are reduced when compared to baseline diesel.***

Index Terms: ***pilot injection, alcohols, performance and emissions***

I. INTRODUCTION

Internal combustion engines have been used extensively in transportation sector as a prime mover. These internal combustion engines are basically categorized as spark ignition engine and compression ignition engine where diesel engines provide with a great amount of thermal efficiency, wider fuel economy and heavy durability on comparing with other engines thus making them one of the most desirable and welcoming choice in the heavy, medium as well as in light duty vehicle applications. Burning of diesel which are great source of hydrocarbons releases harmful pollutants like Nitrides of oxygen (NOx), Carbon-di-oxide (CO2), Hydro Carbons (HC) and smoke. These harmful gases if above prescribed limit proves detrimental to the survival of human being and other animal species. These are important agents for uncontrolled global warming. Therefore it's essential to use advanced or existing better technologies to optimize the engine performance on the whole minimizing the emission levels. There is also a sharp decline of fossil fuel reserves worldwide and degradation of environment by these fossil fuels imposes a greater inclination towards the global warming through the emissions caused by automotive sector. Due to very strict emission norms adopted across the globe a substitute fuels are in great demand. Bi-fuel engine is an method of using regular compression ignition engines where high oxygenated and volatile liquid fuel is been used which has high cetane number used in main injection and diesel in pilot injection, where these mixtures are mixed and helps in better combustion. This engine can be operated by using fuels by blending, fumigation and emulsion methods, but here blending method is been opted. Numerical study was conducted to examine the emissions and the performance characteristics an single cylinder four stoke compression ignition engine which is normally aspirated engine using direct injection strategy which powered with methanol-diesel blends and methanol blended diesel in parts of 5%, to 15% by volume in steps of 5% is been used for the study. The experiment have been accompanied at an engine speed at 1500 rpm for different loads where the use of methanol as an additive in the diesel improved the BTE and BSFC, which are linked to the thorough combustion of fuel blends. Reduction in NOx, and smoke can be attained by Ambarish Dutta, Suhail Dutta and Bijan Kumar Mandal, (2014) [1]. Quangang Wang et al, (2015) studied methanol/diesel bi fuel engines at lower loads using split injection and controlling the intake air temperature are the two main parameters which are responsible for combustion characteristics in a bi-fuel engines. Methanol injected in CI engine at 25% full load had an improvement in the efficiency which is further improved by increasing the temperature in the intake system and slightly increasing the timing of the engine. The engine used here was an inline 4 cylinder DI, turbocharged compression ignition engine and it's been modified to run under DMDF mode, the engine was functioned at continual load of 1660 rpm and at 25% full load. It was observed an increase in BTE when intake temperature was increased above 75 degree Celsius [2]. Engine which is an naturally aspirated one operating at different engine speed in the intervals of 200 rpm varying in-between the range of 1000 to 1800 rpm while maintain the engine torque at 30Nm found in decrease of smoke emissions, CO and THC. The increase of BSFC and decrease of BTE with the use of methanol blended diesel directly associated with the lower heating value of methanol by Cenk sayin, (2010) [3].

Manuscript published on 30 June 2019.
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Experiment has been carried on a six cylinder diesel engine operating on two types of fuel, where air is premixed in the intake manifold and it is injected directly in the engine where the engine operated at fumigation mode, the engine maintained at speed of 1400 rpm with output torque of 270Nm, 648Nm and 1080Nm respectively with engine loads of 25%, 60% and 100%. Emissions were investigated and a decrease in smoke and Nox observed but there was a significant increase of CO and HC emissions by Gang li, Chunhua Zhang and Yangyang Li, (2016) [4]. From the study of Najafi G and Yusaf T F, (2009) the use of methanol blende diesel on a four stroke compression ignition engine were studied for several performance on BTE, BSFC and exhaust temperature. The methanol was blended with diesel in proportion of 10:90, 20:80 and 30:70. Amongst these blends 10% blend were optimal since it produced lowest exhaust temperature. But the BSFC was lower for 30% methanol blended diesel it's been found that a substantial increase in BTE on all blends [15].

From the study of Durai Arasan C V and Vishnu Ganesh B, (2018) the emission characteristics and performance characteristics of a bi-fuel engine was experimented at 3200 rpm and recorded that at part loads the engine performance and emissions were reduced especially high CO and unburned hydrocarbons were emitted. Also the poor performance can be improved at part load by enhancing operating parameters like advancing the injection timing, increasing diesel quantity, injection pressure, multiple injections and by proper intake temperature. BSFC was found to increase by 10% when the methanol is blended with diesel, a 12% increase was observed in the fumigation mode and 17% in the emulsion mode, this improvement in the brake specific fuel consumption can be credited towards the less calorific value of the blend. The fumigation mode tends to increase the emissions except for NOx and CO_2. While using advanced pilot injection it is been observed a major surge in the cylinder pressure and the temperature during the process of combustion, on emissions side it increases oxides of nitrogen (NOx) [5]. From the study of Han Lu et al., (2018) the reasons behind NO_2 generation in the methanol/diesel bi-fuel engine is studied using inline four cylinder compression ignition dual fuel engine. The results presented that the occurrence of methanol premixed in DMDF mode was the important criteria to show an uptrend in the increasing of NO_2 emissions, with the increasing of methanol substitute proportion the NO_2 emissions increased first and then decreased. Implementation of EGR can be an added advantage in the combustion efficiency of DMDF in order to reduce the NOx emissions [6]. From the study of Hongyuan Wei et al., (2017) the effects of split injection on the emission, performance and combustion characteristics of methanol/diesel bi-fuel compression ignition engine using six cylinder with an modified common-rail direct fuel injection system and turbocharger to operate on DMDF mode to study various gaseous emissions like carbon monoxide, hydrocarbons, carbon dioxide, oxides of nitrogen and unburned methanol, while increasing the pilot quantity reduces the hydrocarbon, carbon monoxide and various unregulated emissions of DMDF engine. The use of pilot injection increased the cylinder temperature and the pressure of then cylinder in the engine on comparing with single injections [8].

The feasibility of two stage injection on the performance, emission and combustion characteristics of a single cylinder diesel engine using diesel in main injection and ethanol in the pilot injection which injects on the port of the intake manifold is been studied. While increasing the pilot injection a substantial decrease in the NOx emissions to a certain extent was observed, also soot emissions decreases considerably to a certain level by using pilot injection. On the other side while increasing the pilot injection carbon monoxide and hydrocarbon emissions was increased found by Senthil Kumar k and Thundil Karuppa Raj R, (2013) [9]. From the study of Amin Yousefi et al.,(2015) using multi-dimensional computational model to examine the consequence of numerous premixed fuels and to study the emission, performance and combustion characteristics of a dual fuel indirect injection compression ignition engine, it is observed that the methanol/diesel mixture has maximum IMEP and ITE compared to hydrogen/diesel. According to his findings methanol/diesel premixed mixtures which has high oxygen content produced less soot and CO emissions when operating on richer zones [10].

Mishra C et al., (2013) the suitability of methanol diesel as a fuel in single cylinder compression ignition engine, were studied by taking test fuels in the proportion of 5% and 10% by volume with diesel. Decrease of 10% brake thermal efficiency for 5% blend and 28% reduction were observed for 10% methanol diesel blend on comparing with baseline diesel. BSFC were observed to increase on the increase of quantity of methanol. No significant improvement for NOx emissions were observed for 5% blend but an increase of 11% were noted for 10% methanol diesel blend, consequently HC reduction by 20% was observed [11].

Aekadiuz Jamrozik et al., (2018) the combustion of diesel with alcohol in a diesel engine using a stationary single cylinder bi-fuel engine by using alcohols such as methanol, ethanol, 2-propanol and 1-butanol diesel fuel on the performance, emission characteristics and combustion revealed that the addition of alcohols have a constructive outcome on mean indicated pressure, BTE and stability. Methanol were more beneficial alcohol in terms of performance. It has been reported that highest oxides of nitrogen, carbon monoxide and carbon dioxide emissions were found in methanol additive than other alcohols substitute [12]. From the study of Yusaf T et al., (2013) the option of using methanol as a substitute fuel blend, using four stroke four cylinder compression ignition engine was used which were loaded using 130kW eddy current dynamometer. Methanol were mixed with diesel in the ratio of 0:100, 10:90, 20:80 and 30:70. The test were conducted to study the performance of engine such as torque, BSFC, BTE and exhaust gas temperature by varying the engine speeds. The exhaust temperature were found to be lower for 10:90 methanol composition and power developed was 70% higher than other ratios. Furthermore there was an overall brake thermal efficiency improvement for all blends [13].

From the experiment conducted by S.Srihari et al (2017) the author studied the effect of diethyl ether-biodiesel fueled in direct ignition engine for performance and emissions, a single cylinder four stroke GL grieves 400 engine. The experiment was conducted from no load to maximum of 14Nm load at a constant engine speed of 2000rpm. They found a significant reduction NOx, CO and HC emissions. Brake thermal efficiency was found to be higher for DBD-3. Smoke seems to be lesser for DBD-3. [16]
D.vignesh and S.Srihari (2015) investigated the performance and emission behavior on a single cylinder diesel engine, cotton seed oil and methyl ester in the proportion of 5% to 30% in steps of 5% is been added to diesel fuel as blend. It's been found that a slight increase in brake thermal efficiency was observed at all loads for lower blend percentage. Smoke and other exhaust emissions seems to reduce on the usage of higher bio diesel blends. [17]

Nomenclature

		CH_3OH	Methanol
BSFC	Brake specific fuel consumption	O_2	Oxygen
BTE	Brake thermal efficiency	DMDF	Diesel methanol dual fuel
NO	Nitric oxide	M5	5% Methanol blended diesel
EGT	Exhaust gas temperature	M10	10% Methanol blended diesel
CO_2	Carbon dioxide	CO	Carbon monoxide
HC	Hydrocarbons	SI	Spark ignition
PM	Particulate Matter	rpm	Revolutions per minute
BP	Brake power	kW	Kilo watt
Nm	Newton meter		

II. MATERIALS AND METHODS

In this experimental study the influence of methanol/diesel blends in the proportion of 5% and 10% by volume is been investigated on the emission and performance characteristics of a diesel engine experimentally using a four stroke single cylinder naturally aspirated compression ignition engine. The influence of main and pilot injection by using dual fuel engine is been studied by comparing the diesel-methanol blends with that of baseline diesel for 0%, 10% and 20% pilot injection. The pilot injection for 0%, 10% and 20% have been done experimentally for baseline diesel and for all diesel methanol blends. Exhaust emissions like carbon monoxide, oxides of nitrogen, carbon dioxide and hydrocarbons is been measured and performance parameters like BSFC, BTE and exhaust temperature of the gas are been calculated and measured. All of these parameters for diesel methanol blends and baseline diesel are been calculated at continual engine speed of 2300 rpm. The test engine is been loaded by an eddy current dynamometer at 0Nm, 2.5Nm, 5Nm, 7.5Nm, 10Nm and 12Nm.

A. Fuels

The fuels used here for experiments are methanol (CH_3OH) and diesel (C_{10}-H_{15}). Methanol which is readily available in the commercial market is been used as a blending additive is been purchased from precision scientific company. Diesel has been purchased from authorized Indian oil corporation ltd from Coimbatore. Methanol are alcohols which are oxygenated in nature thus provides more oxygen for better combustion thus promoting uniform combustion in the engines.

Table I Properties of diesel methanol blend 5% by volume

S.No	Pilot injection (%)	Density (kg/m3)	Calorific value(KJ/Kg)
1	0	829.96	42293.4
2	10	830.16	42389.4
3	20	830.37	42486.3

Table II Properties of diesel methanol blend 10% by volume

S.No	Pilot injection %	Density (kg/m3)	Calorific value(KJ/Kg)
1	0	827.93	41323.31
2	10	828.33	41517.71
3	20	828.74	41711.75

Table III Properties of methanol and diesel

S.No	Properties	Methanol	Diesel
1	Chemical formula	CH_3OH	$C_{10}H_{15}$
2	Molecular weight (g/mol)	32	190-220
3	Density (g/cm^3)	0.791	0.832
4	Viscosity (m Pa s)	0.59	2.8
5	Carbon (%wt)	37.5	86
6	Hydrogen (%wt)	12.5	14
7	Oxygen (%wt)	50	0
8	Cetane Number	<5	51
9	Auto ignition temperature	464	316
10	Lower heating value (MJ/Kg)	23	43.26
11	Flash point	11	52

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III. EXPERIMENTAL SETUP

The diesel engine has been mounted on the test bed by screw jacks. Then the engine is connected to the 50 kW eddy current water cooled dynamometer by a shaft coupling to the engine. Alignment such as run in run out and phase in phase out as been done to check the height between the centers of engine shaft and dyno shaft. Phase in and phase out is done to check the correctness of the angle between engine shaft and the dyno. Then the engine connections such as pilot fuel injection tank, connection of battery, auto transformer to supply heat to the intake manifold, pilot controls, and smoke meter and gas analyzers are connected before start of the experiment. A dimmerstat of type 10D-1P of maximum load 10 A has been connected in order to preheat the intake air in the intake manifold to enhance the required temperature for the need of experiment. Horiba 5 gas analyzer and smoke meter are used to measure the smoke and other emissions, Arduino circuit board along with potentiometer is been used to control the pilot injection percentage.

Table IV Engine specifications

Manufacturer	Greaves
Model	GL400
Engine type	4 Stroke naturally aspirated compression ignition engine
Number of cylinders	1 No.
Bore x stroke	86 x 63
Displacement	395cm^3
Compression ratio	18:1
Dry weight	45kg
Maximum engine output @ 3600 rpm	5.5 kW

Table V Horiba 5 gas analyzer: MEXA-584L

Pollutant	Measuring range
CO	0.00% to10% by volume
HC	0 ppm volume to 10,000 ppm volume
CO2	0.00 % volume to 20 % volume
AFR	10.0 to 30.0

Fig.1 Experimental Set-up

IV. RESULTS AND DISCUSSIONS

Brake thermal efficiency

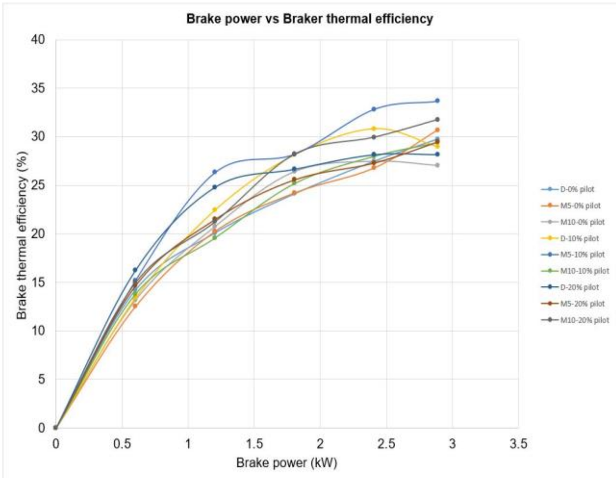

Fig.2 Brake power vs Brake thermal efficiency

Fig.2 shows the comparison of brake thermal efficiency with load. The maximum brake thermal efficiency is observed for 0% pilot injection with 10% methanol diesel blend at all load conditions. Baseline diesel performs better than M5 blend at all loads. An increase of 11.33% in brake thermal efficiency is been observed in M10 blend 0% pilot injection. In the case of 10% pilot there an increase in trend for the BTE for 5% methanol diesel blend at all loads. Baseline diesel performs better than M10 blend at all loads but M10 performs better at high loads. It is been observed that an increase of 13.98% in BTE has been observed in M10 blend 10% pilot injection. M5 blend provides desirable performance at all load conditions. At 20% pilot injection there is an increasing trend in the brake thermal efficiency for 10% methanol diesel blend at higher loads. Baseline diesel performs better than M10 blend at lower loads but M10 performs better at higher loads. It is been observed that BTE has increased by a percentage of 11.33 in M10 blend 20% pilot injection. Finally M10 blend provides desirable performance at all loads.

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Brake specific fuel consumption

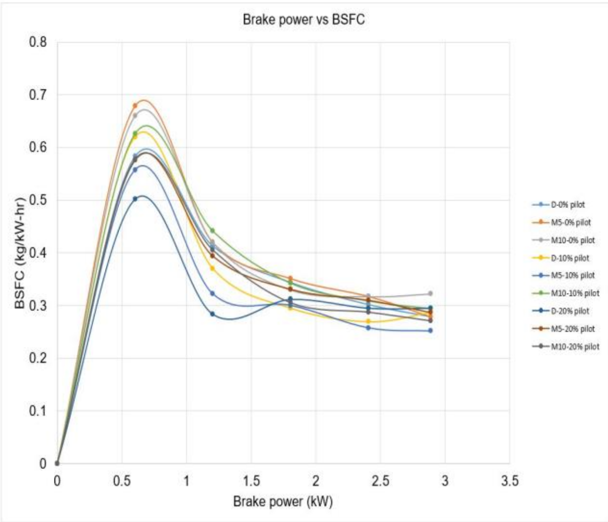

Fig.3 Brake power vs BSFC

The effects of methanol-diesel blends on the BSFC is presented in Fig.3. It is observed that as the brake power increases, the BSFC decreases for baseline diesel and other blends at 0% pilot injection. At all loads diesel provides lower BSFC compared to blends there is an increase of 13.28% of BSFC for methanol diesel blended fuel compared with diesel. Among the blends for 0% pilot injection M5 blend gives lower BSFC. For 10% pilot injection as the increase in brake power the BSFC decreases for baseline diesel and for all type of blends. At intermediate and higher loads methanol blended fuel M5 provides lower BSFC compared to diesel and M10. There is decrease of 2.57% of BSFC for M5 compared with diesel. Among the blends and baseline diesel for 10% pilot injection M5 blend gives lower BSFC. At low loads diesel gives lower BSFC compared to blends M5 and M10.The BSFC is lower for diesel at low loads but increasing loads M10 gives lower BSFC, at medium and high loads M10 provides reduced BSFC. M5 gives higher BSFC throughout the engine load. There is decrease of 8.025% in BSFC while using M10 while using at 20% pilot injection.

Exhaust gas temperature (EGT)

The EGT increases as the load of the engine increases and is shown in Fig. 4. M5 blend has lowest exhaust gas temperature compared to M10 with 0% pilot injection, at all loads. Overall the blended fuel gives better result compared to baseline diesel. There is a decrease of exhaust gas temperature of M5 by 7.95% compared with baseline diesel and decrease of 6.36% compared baseline diesel with M10.It was observed that for 10% pilot injection as the load increased EGT increased, the M5 fuel has low EGT compared to M10 and baseline diesel fuel. Overall the methanol blended diesel produces lower EGT compared to baseline diesel.

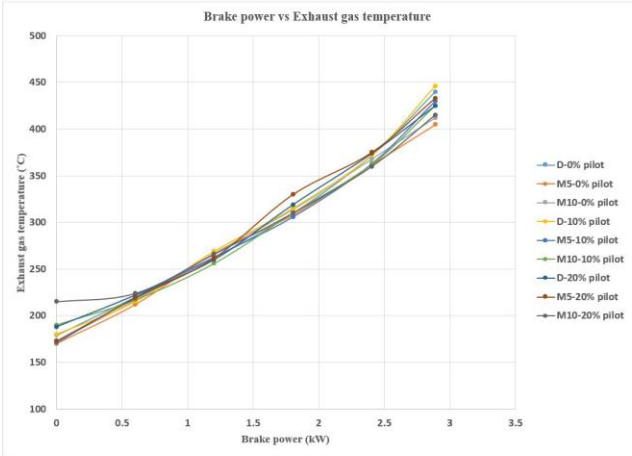

Fig.4 Brake power vs Exhaust gas temperature (EGT)

This is due to presence of oxygenated methanol blend in diesel which improves the combustion characteristics of the blend. There is a decrease of exhaust gas temperature of M5 by 2.72% compared with baseline diesel and decrease of 3.4% compared baseline diesel with M10. It was observed that for 20% load as the load increased EGT increased, the M10 fuel has low EGT at higher loads when compared to M5 and baseline. At low loads baseline diesel has lower EGT compared to M5 and M10 blends. Overall the methanol blended diesel produces lower EGT on comparing with to baseline diesel. There is a reduction of 2.35% in exhaust gas temperature of M10 when compared with baseline diesel and 4.15% when compared with M5 blend.

Smoke emissions

Smoke emission is increased due to lean air fuel ratio which causes incomplete combustion, resulting in smoke formation and is shown in Fig. 5. Among the baseline diesel and blends diesel has higher smoke content for all loads, the graph shows lesser smoke is been observed for methanol diesel blends. At lower loads M10 emits lower smoke and at higher loads M5 emits lesser smoke. M5 emits 23.61% lesser smoke when comparing with diesel and M10 emits 18.11% lesser smoke than baseline diesel. While engine is running under 10% pilot injection the baseline diesel and blends M5 has higher smoke content for all loads, the graph shows lesser smoke is been observed for methanol diesel blend M10. At all loads M10 emits lower smoke and diesel emits moderate smoke on all loads. M5 emits 15.84% higher smoke when compared with diesel and M10 emits nearly 48.02% lesser smoke than baseline diesel at no load condition, 48.78% lesser smoke in medium load condition and 20.26% lesser smoke at high load condition. While using 20% pilot the baseline diesel and blends diesel has higher smoke content for all loads, the graph shows lesser smoke is been observed for methanol diesel blend M10 at higher loads and lesser smoke for methanol diesel blend M5 at lower loads. M5 emits 19.82% lesser smoke at low loads, 15.21% lesser smoke at medium loads and 14.31% lesser smoke at high loads when compared with diesel.

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M10 emits 53.61% lesser smoke at low loads, 27.58% lesser smoke at medium loads and 14.58% lesser smoke at high loads when compared with diesel. The low smoke content from blends is due to complete combustion of fuels, this can be attributed towards the presence of high amount of oxygenates present in the blended fuel.

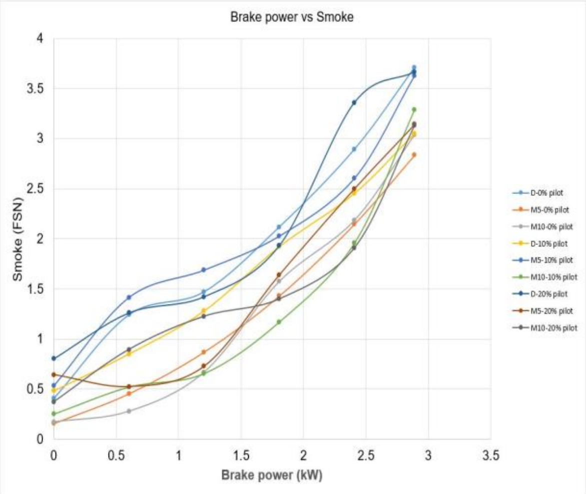

Fig.5 Brake power vs Smoke

Carbon monoxide emissions

Variation of Carbon monoxide emissions with load is presented in Fig.6. The results showed that when operated on 0% pilot injection, emissions remained unchanged for M10 blend and diesel at all loads. CO emissions are higher for M5 at lower loads and does not vary at higher loads. CO emissions were found to be less for M10 for wide range of engine loads due to cleaner combustion while comparing with M5 and diesel. M5 blend emits higher CO content than baseline diesel. At no load M10 produced 33.33% higher CO content than baseline diesel, at medium loads there was decrease in emissions by 57.14% compared with diesel and at higher loads there was 25% decrease in CO emissions compared with diesel. The trend for M5 emissions increased initially at lower loads and decreased as loads increased, but for 10% pilot injection, it is observed that emissions were lower for M5 at all loads followed by M10 and finally diesel. At no load M5 produced 36.36% lower CO content than baseline diesel, at medium loads by 42.85% compared with diesel and at higher loads there was 33.33% carbon dioxide emissions was found to be less by 33.33% compared with diesel. At no load M10 produced 45.45% lower CO content than baseline diesel, at medium loads by 14.28% compared with diesel and at higher loads there was 40% increase in CO emissions compared with diesel.

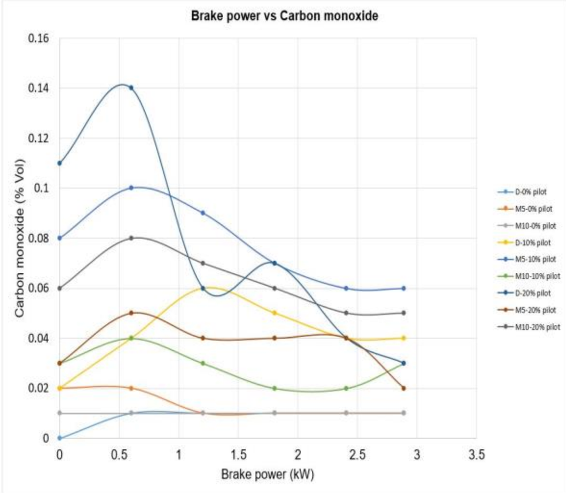

Fig.6 Brake power vs Carbon monoxide

Carbon dioxide emissions

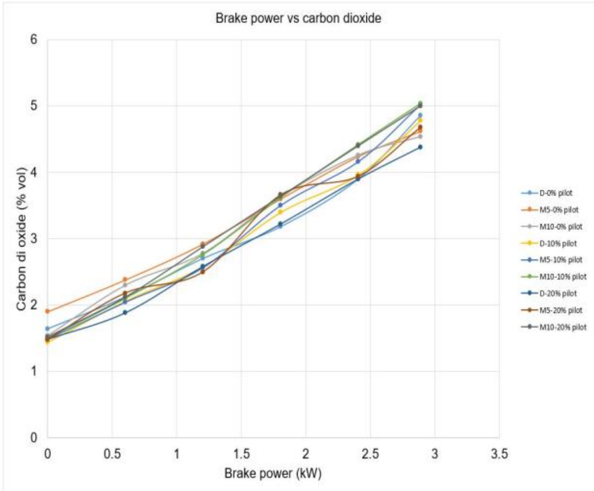

Fig.7 Brake power vs Carbon dioxide (CO_2)

Carbon dioxide is a combustion product of hydrocarbon fuel. CO_2 emissions are increased as the load on the engine is increased for methanol-diesel blends which is shown in Fig. 7. It is noticed that at 0% pilot injection methanol blended diesel has higher CO_2 emissions compared with diesel owing to presence of more oxygen content in the M5 and M10 promotes the formation of carbon dioxide. M5 emits 14.73% higher carbon dioxide at no load, 7.53% higher CO_2 at medium loads and 4.93% higher CO_2 at high loads compared with baseline diesel. M10 emits 4.93% lesser CO_2 at no load, 12.63% higher CO_2 at medium loads and 6.58% lesser CO_2 at higher loads, but for 10% pilot injection, it is observed that as the load on the engine increases CO_2 emissions also increases for diesel and blends. It is found that 10% pilot injection methanol-diesel has higher CO_2 emissions compared with that of diesel. M5 emits 2.7% higher carbon dioxide at no load, 0.77% lesser CO_2 at medium loads and 4.78% higher CO_2 at high loads compared with baseline diesel.

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M10 emits 4% higher CO_2 at no load, 6.07% higher CO_2 at medium loads and 5.15% higher CO_2 at higher loads. While engine is operating on 20% pilot injection, it is observed that the CO_2 emissions increases as the load on the engine is increased for diesel and blends. It is been observed that at 20% pilot injection methanol blended diesel has higher CO_2 emissions compared with diesel. M5 emits same emission as diesel at no load, 12.02% higher CO_2 at medium loads and 6.41% higher CO_2 at high loads compared with baseline diesel. M10 emits 2.63% higher CO_2 at no load, 11.53% higher CO_2 at medium loads and 12.4% higher CO_2 at higher loads.

Hydrocarbon emissions

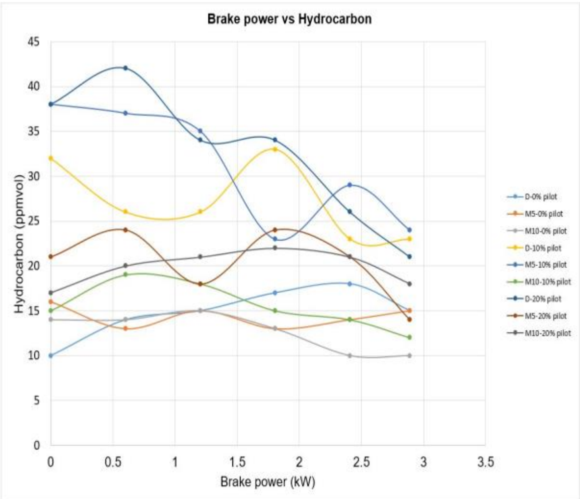

Fig.8 Brake power vs Hydrocarbon

HC emissions are increased as the load on the engine increases which is shown in Fig. 8. M10 produced more HC emissions at medium loads and lower HC emissions at higher loads. M5 produced higher HC emissions at low loads and lower HC emissions at high loads. At zero load condition diesel emits lower HC emissions, at lower loads M5 emits 37.5% higher HC emissions compared to diesel, 23.5% lesser HC emissions at medium loads and no change at higher loads. At zero load M10 emits 28.57% higher HC emissions, 25.52% lesser HC emissions at medium loads and 33.33% lesser HC emissions at high loads when compared with baseline diesel. But on contrast while operating on 10% pilot injection, it is witnessed that as the load on the engine is increasing the HC emissions decreases for diesel and both the blends. M10 produces lesser HC emissions at all loads on the other side M5 produces higher HC emissions at low loads and lower HC emissions medium loads. Initially at zero load M10 emits lower HC emissions, at lower loads M10 emits 26.92% lower HC emissions compared to diesel, 54.54% lesser HC emissions at medium loads and 47.82% lesser HC emissions at higher loads. At zero load M5 emits 15.78% higher HC emissions, 30.3% lesser hydrocarbon emissions at medium loads and 4.16% higher HC emissions at high loads when compared with baseline diesel. Using 20% pilot injection, it is observed that as the load increases the HC emissions decreases for both diesel and blends. Hydrocarbons are formed due to insufficient temperature available for combustion but here due to presence of oxygenated alcohol blends provides sufficient oxygen available for combustion thus temperature at the cylinder walls are higher, due to which lesser HC emissions are achieved. Among diesel and blends, methanol blended diesel fuel emits lesser HC emissions. M10 emits 55.26% lesser HC at no load, 38.23% lesser HC at medium loads and 14.28% lesser HC at high loads when compared with diesel. M5 emits 44.73% lesser HC at no load, 29.03% lesser HC at medium loads and 33.33% lesser HC at higher loads when compared with diesel.

NOx emissions

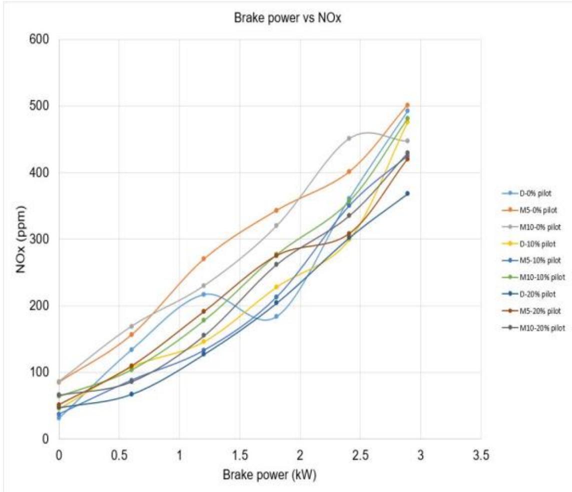

Fig.9 Brake power vs NOx

Fig. 9 shows the comparison of NOx with loads for all the operating modes. It is observed that as the load increases the NO_x increases for all loads with 0% pilot injection. Diesel emits lesser NO_x than M5 and M10 because since methanol fuel contains higher amount of oxygen which increases the combustion temperature of the exhaust gases thus promoting the NO_x formation. M5 emits 63.52% higher NO_x at no load, 17.2% higher NO_x at medium loads and 1.79% higher NO_x at higher loads when compared with diesel. On the other hand M10 emits 63.95% higher NO_x at no load, 11.25% higher NO_x at medium loads and 9.14% lesser NO_x at high loads when compared with baseline diesel, but for 10% pilot injection, it is observed that as the load increases the NO_x increases for all loads and fuels. Diesel emits lesser NO_x than M5 and M10. M5 emits 17.77% lesser NO_x at no load, 6.57% lesser NO_x at medium loads and 10.52% lesser NO_x at higher loads when compared with diesel. On the other hand M10 emits 29.68% higher NO_x at no load, 17.97% higher NO_x at medium loads and 1.24% higher NO_x at high loads when compared with baseline diesel. When plotting for 20% pilot injection, with the increase of load the NO_x also increases for all loads and fuels. Its lesser NO_x than M5 and M10 at all loads.

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M5 emits 7.84% higher NO_x at no load, 25.81% higher NO_x at medium loads and 12.38% higher NO_x at higher loads when compared with diesel. On the other hand M10 emits 28.78% higher NO_x at no load, 22.13% higher NO_x at medium loads and 14.21% higher NO_x at higher loads when comparing with baseline.

V. CONCLUSIONS

In this experiment, the effect of pilot injection and main injection on the performance and emission characteristics of a single cylinder compression ignition engine was experimentally investigated at constant load of 2300 rpm at loads of 0Nm, 2.5Nm, 5Nm, 7.5Nm, 10Nm and 12Nm was studied using baseline diesel and methanol blended diesel in proportion of 5% by volume and 10% by volume with diesel. The blends M5 and M10 has been studied using 0%, 10% and 20% pilot injection and was compared with the baseline diesel to benchmark the behavior of methanol blended diesel for emissions and performance. The important conclusions can be drawn from the experimental results of M5 and M10 alcohol diesel against various engine loads for the baseline diesel are as follows

- BTE was higher for Methanol blended diesel when operating on 10% pilot injection. The maximum brake thermal efficiency achieved was 33.68% at high loads. Followed by M5 which achieved 31.77% BTE at high loads and the least was diesel which attained 30.84%. The main reason for this behavior is presence of rich amount of oxygen present in the alcohols which promotes the proper combustion of fuels thus achieving higher BTE. While preheating the intake air at 160˚C the combustion delay was decreased and the increase of intake temperature aided proper flame propagation thus increasing the BTE.
- Exhaust gas temperature (EGT) is lesser in M5 blend at 0% pilot injection due to uniform flame propagation thus promoting proper combustion.
- BSFC was lower for M5 blend at 10% pilot injection at higher loads.
- Smoke was observed to be less in both the M5 and M10 blends at 0% pilot injection which is due to the uniform fame propagation in the charge and presence of enough oxygen for complete combustion.
- Carbon monoxide (CO) emissions was less for M10 blend at 0% pilot injection which increased for baseline diesel and M5.
- Hydro carbon emissions were found to be less for both M5 and M10 methanol blended diesel due to presence of high amount of oxygen content in the fuel which promotes in complete combustion of hydrocarbon diesel fuel present in the blend.
- It was observed that CO_2 increased as the blend ratio is increased, CO_2 was observed to be less for baseline diesel since presence of oxygen in the alcohol blends promotes the formation of CO_2 which is less in case of diesel.
- NO_x was found to increase in both M5 and M10 blends owing to the occurrence of high amount of oxygen in the methanol fuel which increase the combustion temperature thus the in cylinder temperature and thereby promoting NO_x formation. NO_x was found to be less in 20% pilot injection in diesel fuel.

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