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Experimental Study on Digital Twin Spark Ignition Gasoline Engine at Different Gasoline-Methanol Blends

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Abstract

The effect of methanol-gasoline blends on the engine performance and combustion characteristics have been investigated experimentally. In this work a 4-storke cylinder digital twin spark ignition engine is used. The tests were performed at different loads for blends such as M10, M15, M20, M25, M30, as well as for pure gasoline also at 32°BTDC for one spark plug and 28°BTDC for the other one. The results shows improvement in physical properties by adding methanol since methanol is volatile than gasoline. The experimental results revealed that the fuel consumption and brake thermal efficiency is increased by increasing methanol content in blends. The emission results shows decrease in CO, UBHC, NOx.

Keywords: DTSi, Gasoline, Methanol, UBHC

INTRODUCTION

Several concerns such as global warming, environmental degradation and energy security have increased the emergency for finding alternatives to fossil fuels. Even though, the fossil fuels are being used safely, they take a toll on the atmosphere by increasing pollution and thus increasing global warming. These phenomenon trigger an interest in the use of renewable energy fuels. As alcohols have low global warming potential they are preferred for SI engines [1,2]. Methyl Alcohol(CH_3OH), widely known as methanol is formed from organic compounds called alcohols. There are several ways of producing methanol, for instance from synthesis gas, gasification of coal, from biomass. These raw materials required for the production of methanol are found in abundance [3,4].

In recent years many experiments have been conducted on the usage of methanol or methanol gasoline as a fuel for spark ignited engine. Using low content rates of alcohol-gasoline(methanol and ethanol) under wide open throttle(WOT) condition, shows a decrease in CO and HC emissions and an increase in the engine torque, brake power and volumetric efficiency in comparison with operating the same with pure gasoline[5]. There is significant reduction in CO and NO_X emissions using 10, 20, 85% methanol-gasoline blends in SI engines with the increase in methanol fraction in the fuel blend[6]. The emission of NO_X and CO reduced with increase in thermal efficiency when the engine is tested with methanol and ethanol as alternative fuels[7]. Experimental studies were conducted on the emissions in SI engine using methanol-gasoline blends by adding ethanol as a co- solvent shows reduction in NO_X emission and an increase in HC emission for M25(gasoline having 6 vol % ethanol and 19 vol % methanol) than those of gasoline and M10(gasoline having vol % ethanol and 8.5 vol% methanol) for all engine loads. The emission of CO was higher using gasoline than methanol-gasoline blend, for low and moderate loads. However, for high loads, that of M25 was higher[8]. The comparative study on two flex-fuel shows decrease in the CO and NO_X emissions, while using methanol [9].

In this work an attempt is made to use gasoline-methanol blends as fuel in digital twin spark ignition engine. The combustion will be more efficient in this compared to single spark plug engine. The two spark plugs are fixed at two ends of cylinder head helps in proper combustion also reduces the flame travel distance. For the experimental work blends are prepared on volume basis and physical properties of all blends found using standard equipment. The performance parameters like brake power, Indicated power, friction power, brake thermal efficiency, indicated thermal efficiency, mechanical efficiency, total fuel consumption brake specific fuel consumption are evaluated. The engine is also tested for emission characteristics. The experimental results shows improvement in bake thermal efficiency. The percentage of CO and UBHC is reduced for higher blends.

EXPERIMENTAL INVESTIGATION

A single cylinder four stoke variable compression ratio engine is used in the work. The spark plugs are fixed at two ends of the cylinder head. The engine was able to run at different compression ratios varying from 4.5 to 10.5. In this work the engine is tested at fixed compression ratio 10. Specification of the engine is listed in table1. The blends are prepared on volume basis and then poured into fuel tank which is provided with measuring burette. Since the calorific value of methanol is lesser than gasoline little modification made in carburetor main jet to increase the flow rate of fuel. The excess air ratio was fixed by adjusting air adjustment screw.

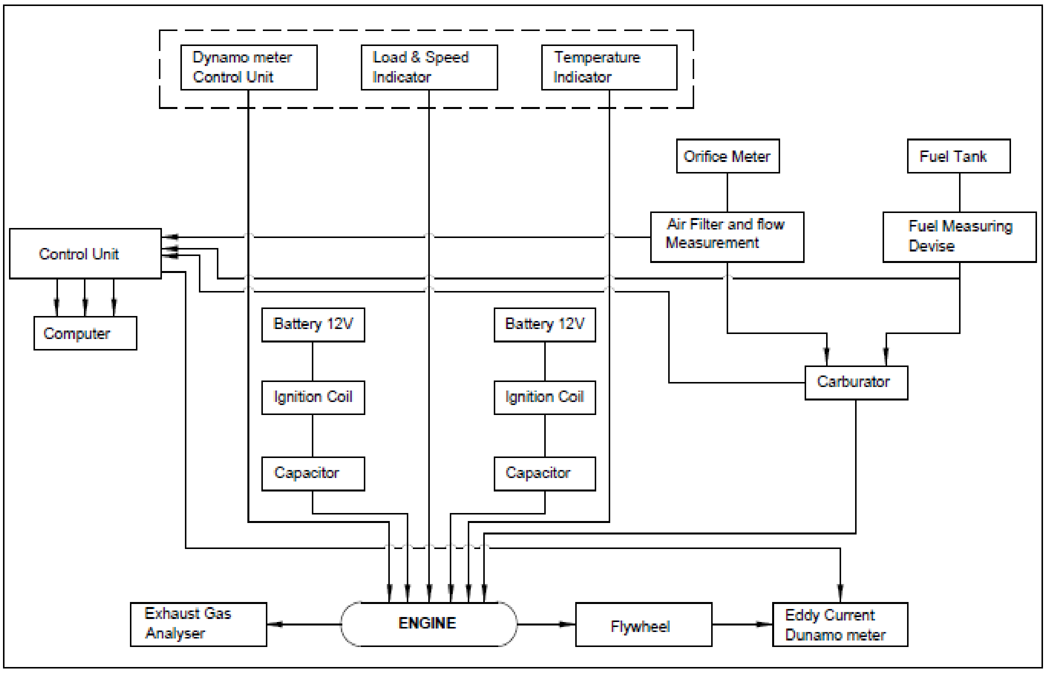

Figure 1: Schematic diagram of Engine setup

Table 1: Engine Specification:

Type	4-stroke
No of Spark plugs Rated power	02
	2.8 kW @ 3000 Rpm
Bore and Stroke	70mm and 66.7 mm 256cc
Swept Volume	9.5
Compression ratio	Water Cooling
Type of cooling	

RESULTS AND DISCUSSIONS:

A. Engine performance

In the operation of engine with gasoline-methanol blends, methanol is an oxygenated fuel will provide more oxygen in the combustion chamber helps in better combustion. The physical properties of blends show better results for higher percentage of methanol. The flash point, fire point, viscosity is reduced significantly with increasing the methanol content. The variation of TFC with respect to different load is presented in the figure2. In can be observed from the graph that fuel consumption is increased for all blends compared to gasoline. This is well known that calorific value of methanol is lesser than gasoline. To overcome that power loss flow rate of fuel has been increased. However it shows improvement in brake thermal efficiency. Experiments were conducted at different loads with fixing crank angle 32° BTDC for one spark and 28° BTDC for the other one. The emission parameters are determined with the help of gas analyzer. The Figure 1 shows the schematic diagram of test engine.

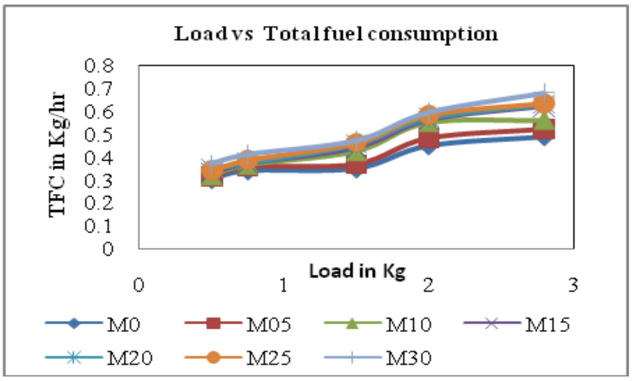

Figure 2: TFC variation with respect to load

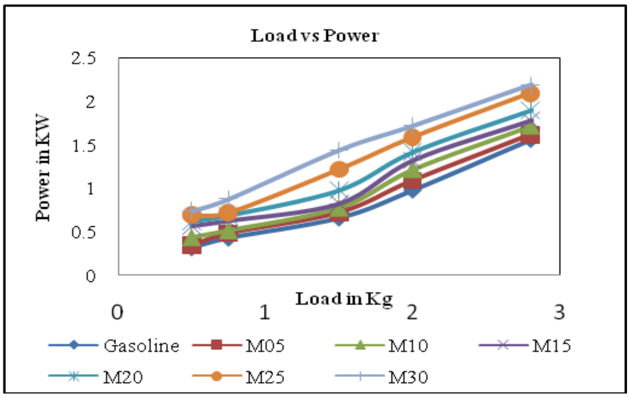

Figure 3: Brake power variation with respect to load

The effect of gasoline and gasoline-methanol blends on engine power can be observed in Fig.3. The power obtained with gasoline is 1.22KW at maximum load. Power obtained for blends varies from 1.62KW to 2KW. The engine power is increased by about 13% at the minimum load. There are many reasons to consider for increasing power using methanol blends is explained in brake thermal efficiency discussion. The increase in torque is an important reason for increasing the power.

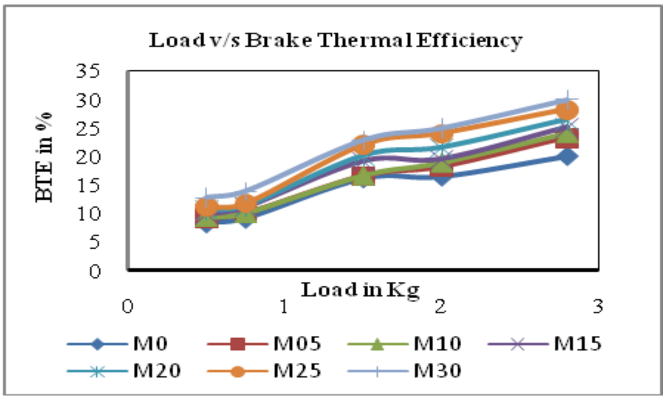

Figure 3: Brake thermal efficiency variation with respect to load

The effect of gasoline and methanol fuels on brake thermal efficiency at different loads is shown in fig.3. The maximum brake thermal efficiency obtained by gasoline is 19.8%. The value of brake thermal efficiency is significantly increased by using methanol with gasoline. The maximum BTE obtained at M30 is 30%. At the same engine working conditions brake thermal efficiency is about 18% higher than that with gasoline. One of the major reason for increasing thermal efficiency by methanol blends is that, methanol has higher laminar flame speed than most of the hydrocarbon fuels [10,11]. The higher flame speed helps in completing the combustion process before heat losses from the cylinder, increases thermal efficiency. Second reason is that, methanol has more oxygen compared to gasoline. This will help in complete combustion. The third reason is higher heat of vaporization of methanol. During the vaporization methanol absorbs more heat from the cylinder in the compression stroke will reduces the work required for compressing air fuel ratio. This also increases the thermal efficiency.

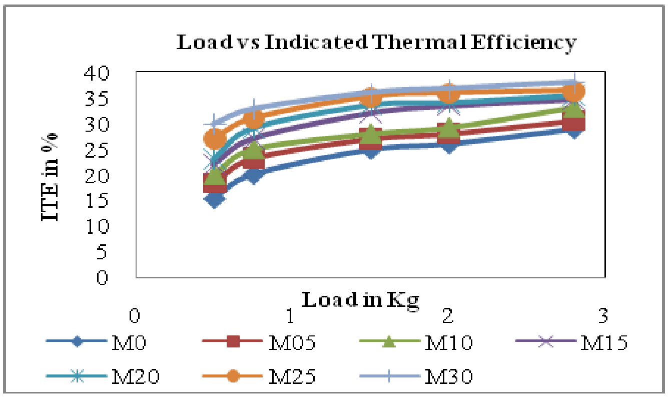

Figure 4: Indicated thermal efficiency with respect to load

The changes in indicated thermal efficiency at different load for various blends are given in Fig.4. The ITE for all blends is increased compared to gasoline. The ITE is improved around 8.3% with M05, 8.2% with M10, 7.6% with M15. The maximum increase in ITE is about 28% at maximum load compared to gasoline. Since methanol has higher heat of vaporization the cylinder pressure is comparatively high by using methanol compared to gasoline. This tends to increase the indicated power as well as indicated thermal efficiency.

b. Exhuast Emissions

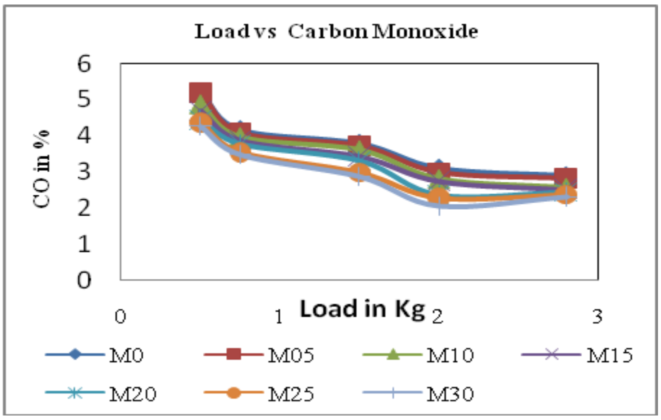

Figure 6: Carbon monoxide variation with respect to load

The variation of CO with gasoline and different blends with respect to load is shown in fig.6. For all blends CO emission is decreased. For increasing methanol percentage in blends CO emission is decreased. The higher operating temperature at higher load helps in better combustion decreases the CO emission. The value of CO obtained for gasoline is 5.6% and decreased about 7.4% for M05, 9.2% for M10, 11.5% for M15, 15% for M20, 18.2% for M30. The maximum reduction in CO at higher load is about 19%. CO emissions mainly depend on A/F ratio. CO emission decreases for methanol blends because of oxygen enrichment. As the load increases CO emission decreases due to increase in cylinder temperature. At higher temperature oxidation of CO increases [10,14].

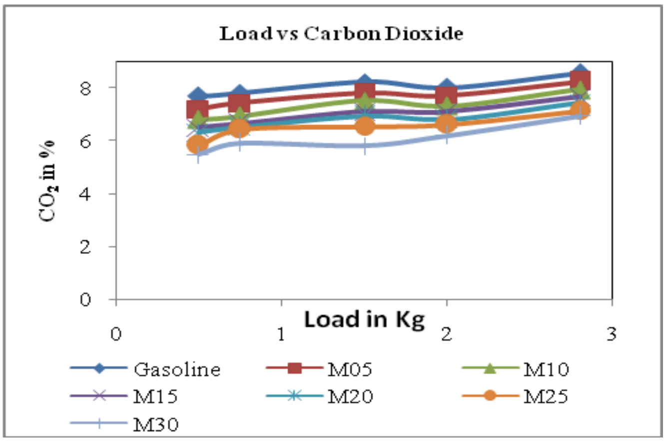

Figure 7: Carbon dioxide variation with respect to load

The CO_2 emission with respect to various gasoline-methanol blends is shown in Fig.7. The CO_2 emission shows increasing trend for increasing load but decreases for increasing methanol content in the blend. The maximum decrease in CO_2 was about 17% at maximum load. Most of the researchers stated that emission of CO_2 mainly depends on C/H ratio in the fuel [12,13,15]. Because of less C/H ratio and C content in methanol the blends are showing less CO_2 emission compared to gasoline. Another reason for increasing CO_2 is high oxygen content of the methanol. This helps in convert carbon into carbon dioxide in combustion instead of leaving as CO.

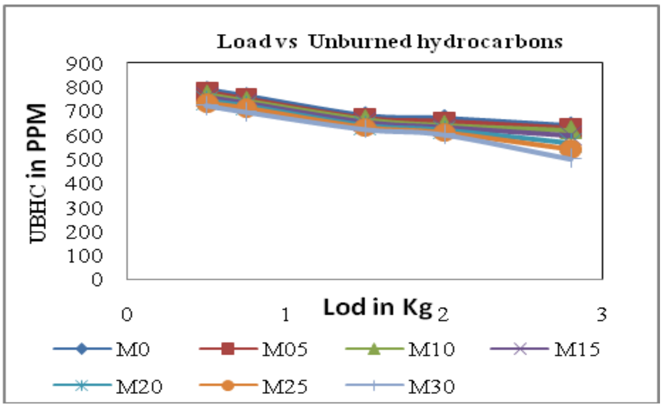

Figure 8: Unburnt hydrocarbon variation with respect to load

The main reason for unburned hydrocarbon is improper mixture and incomplete combustion. The other reasons encountered are misfires, exhaust vale leakage, valve overlapping, crevices and lubricating oil deposits on the combustion chamber wall[16,17]. In this work the unburned hydrocarbon emission for gasoline and different blends is plotted in Fig.8. Compared to gasoline the emission of HC reduces by increasing methanol content in blends. However for higher loads the HC emission decreases because of higher operating temperature. The oxygen content of methanol fuel remarkably decreases the HC emission.

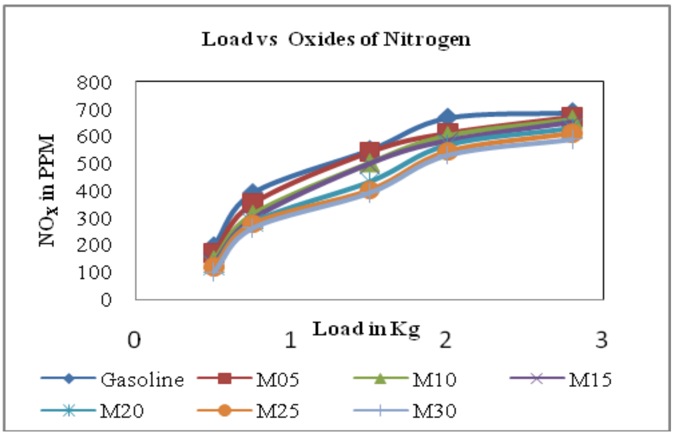

Figure 9: Oxides of Nitrogen variation with respect to load

The Fig.9 elaborates the effect of gasoline and gasoline-methanol blends on NOx. The NOx emission is decreased for all blends compared to gasoline. NOx is decreased about 2.9% for M05, 2.3% for M10, 3.1% for M15, 2.1% for M20 and 2.8% for M30. There is almost 17% reduction in NOx emission for M30 compared to gasoline. The reason for NOx reduction is higher heat of vaporization of methanol than gasoline. This reduces the engine intake temperature intern decreases combustion temperature.

CONCLUSIONS

In this work, the effect of methanol on performance and emission was investigated experimentally in a single cylinder 4-stroke variable compression ratio SI engine provided with two spark plugs. The results shows increase in thermal efficiency. But power is slightly decreased however the thermal efficiency is increasing. Owing to the point, lower heating value of methanol than that of gasoline the specific fuel consumption is increased. But this increase in SFC is recovered in increase in thermal efficiency.

The experimental result also revealed that there is significant reduction in CO, NOx and HC. At the lower blends the decrease in CO, NOx and HC is about 6.5% at lower loads. However overall decrease in emissions is about 17% at maximum load.

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