Performance and Emission characteristics of Digital Twin Spark Ignition Engine working on Gasoline – Methanol Blends

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Abstract : The high knock resistant and low emission make the methanol a best suitable alternative for gasoline. High octane number and heat of vaporization allows to run at higher temperature. The effect of methanol and gasoline blends as well as neat methanol on engine performance and emission parameters have been experimentally investigated. A four stroke petrol engine with twin spark ignition engine is used for this experimental study. The work is carried out at different loads for the blends such as M0, M20, M40, M60, M80 and M100 on mass basis. The spark plugs are situated in the engine cylinder in opposite direction. The spark produced by two spark plugs at different intervals such as 32^o BTDC - 28^o BTDC. The performance and emission parameters are determined at two different spark timings such as 32^o BTDC - 28^oBTDC and 26^oBTDC - 24^oBTDC at the fixed compression ratio 10:1 for all blends. The experimental results inferred that, better performance and emission characteristics can be obtained by adding methanol with gasoline since it is volatile and has higher octane number than gasoline. The experimental results also revealed that 28^oBTDC - 26^oBTDC spark ignition combination increases the thermal efficiency with decreasing CO, UBHC, as well as NO_x.

Keywords —DTSi, Metahnol, CO, UBHC, NOx, BTDC.

I. INTRODUCTION

Now a days fossil fuels are also being used for fuel production. The fossil based fuel's reserves are not able to replenish. There is a need of alternative renewable resource as the fossil based fuels when used in Internal Combustion engines produce pollutants like CO, HC, NOx and particulate matter [1]. The main objective of recent studies is that to improve the performance of the engine and reducing the polluting products with the usage of renewable and reliable resources [2]. The alcohols which include ethanol, methanol and butanol can also be a resource as it has high evaporation and octane values which permits it for being used as a fuel for high CR engines with high powers resulting in improvement. The input fuel-air mixture is cooled by high heats of evaporation resulting in a denser form which will improve the output power [3]. The final result is an improvement in the volumetric efficiency because of the high auto-ignition temperatures of alcohols. The auto-ignition temperatures of gasoline is lesser than those of alcohols. Moreover the temperature of the intake manifold lower because of the heat of evaporation of alcohol is 3 to 5 times higher than that of gasoline increasing the reliability of safety on transportation and storage [4]. Methanol has a higher laminar flame speed when compared to other hydrocarbon fuels [5, 6]. Hence there will be an augment in thermal efficiency as the combustion process is completed early making decrement in heat losses from the cylinder. Moreover the exhaust will have particulate matters and nitrogen oxides in small compositions when compared to gasoline ejection products [7]. The gasoline- methanol blends are more oxygenated because of the presence of an oxygen atom in the methanol molecule and this will lessen the emissions of CO and hydrocarbon thereby better combustion of the fuel [1, 6]. The availability of methanol is very easy as it can be made from coal, biomass, natural gas, sewage and municipal solid wastes [1].

A multitude of experiments and studies have been conducted on the use of methanol and gasoline -methanol blends as a source of fuel in the SI (Spark Ignition) engines. Prospects of using alternative fuels in the spark ignition engines were experimented and theoretically studied by several researchers. In consequence of using pure ethanol and methanol as fuels in their experiments they were rewarded with a considerable decrease in the emissions of CO and NOx gases and an increased thermal efficiency of the (SI) spark ignition engine [8]. The experiment conducted on SI engine at different gasoline – methanol blends, resulted in increased fuel consumption due to usage of methanol infractions but as an compensatory effect the carbon emissions reduced appreciably [9]. In another experiment conducted on engine with methanol as fuel, emission reduced along with engine

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power but an increase in fuel consumption was recorded [10]. Three methanol-gasoline blends of M10, M20, and M85 were prepared to study the effects of these fuels on engine power, thermal efficiency and emissions. These results do not defer from previous citations claiming that usage of methanol reduces CO and NOx emissions appreciably along with improved thermal efficiency [11]. It was also keenly observed that as parts on methanol increased in the blends the emissions of CO and NOx further reduced. Particularly the M85 blend emerged with a reduction in CO gas by 25 % and NOx emission by 80% which was satisfying .

II. METHODOLOGY

A four stroke single cylinder twin spark ignition engine was used for experimental work. The engine was able to run at different compression ratios ranging from 6:1 to 13:1. It is well known that larger quantity of methanol has to be supplied to the engine for getting energy equivalent to gasoline. The engine was facilitated with loading system and control unit to measure the cylinder pressure at different loading conditions. Figure 1 shows the schematic layout of test rig. Small alteration made in the carburetor main jet for this purpose. The excess air ratio was adjusted with the help of adjustment screw.

III. RESULTS AND DISCUSSIONS

A. *Engine Performance*

The test engine was run under different load conditions varying from 2kg to 10 kg at full throttle condition. It was tested for different gasoline – methanol blends such as M0 to M100. M0 indicates the zero percentage of methanol content nothing but gasoline. Similarly M100 is neat methanol. The physical properties of different blends shown reduction in flash point, fire point as well as viscosity with increase in percentage of methanol in the blends. Since methanol has higher oxygen content helps in increasing the combustion efficiency.

The fuel consumption with respect to load for different blends at 32° BTDC – 28° BTDC and 26° BTDC – 24° BTDC are labeled in the figure 2 and Figure 3 respectively. It is known that, having less calorific value of methanol leads to increase in fuel consumption by increasing the methanol content in the blend. To overcome the power loss the fuel supply is adjusted at the main jet of carburetor. However the efficiency of the engine has been increased by increasing the methanol percentage in blends due to higher octane number and better combustion. The increase in fuel consumption at the lower load is about 42% and at the higher load is about 38.12%. By comparing the fu8el consumption at different spark timings, the 26° BTDC – 24° BTDC combination consumed less fuel than other. The decrease in fuel consumption is due to complete combustion by producing spark at 28° before top dead center instead of 32° before top dead center. When spark is initiated at 32° BTDC most of the fuel is wasted before cylinder reaches TDC.

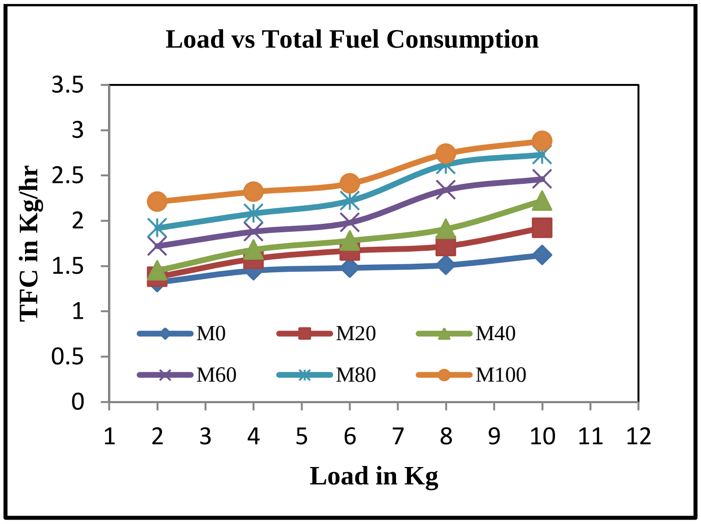

Figure 2: TFC with respect to Load at 32° BTDC - 28° BTDC

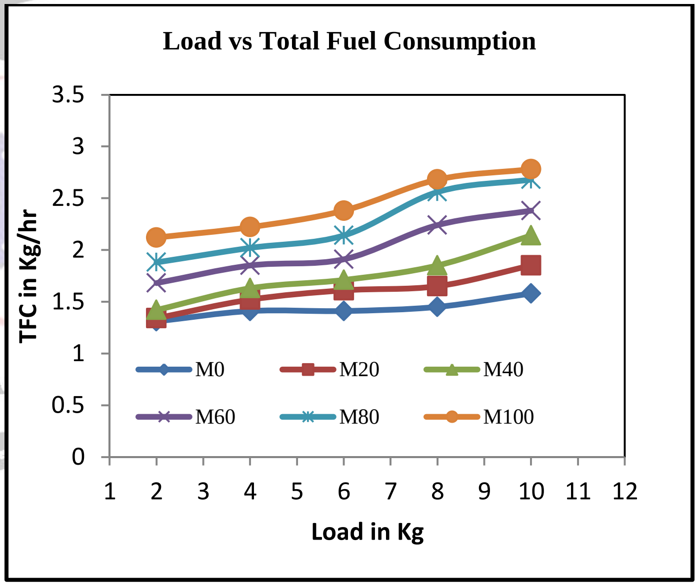

Figure 3: TFC with respect to Load at 26° BTDC - 24° BTDC

The brake power produced at different loads with respect to different spark ignition combination is presented in the figure 5 and Figure 6 respectively. It can be observed from the figure that, brake power increases at the higher load. Since the engine operating temperature is higher at the higher loads leads to get complete combustion helps in increasing the brake power. It is also observed that the brake power increases by increasing methanol content in the blends. The increase in brake power at the lower is about 28% and at the higher load is about 24.4%. The increase in brake power is due to the presence of higher oxygen in methanol. The oxygenated fuel helps in complete combustion leads to produce more power.

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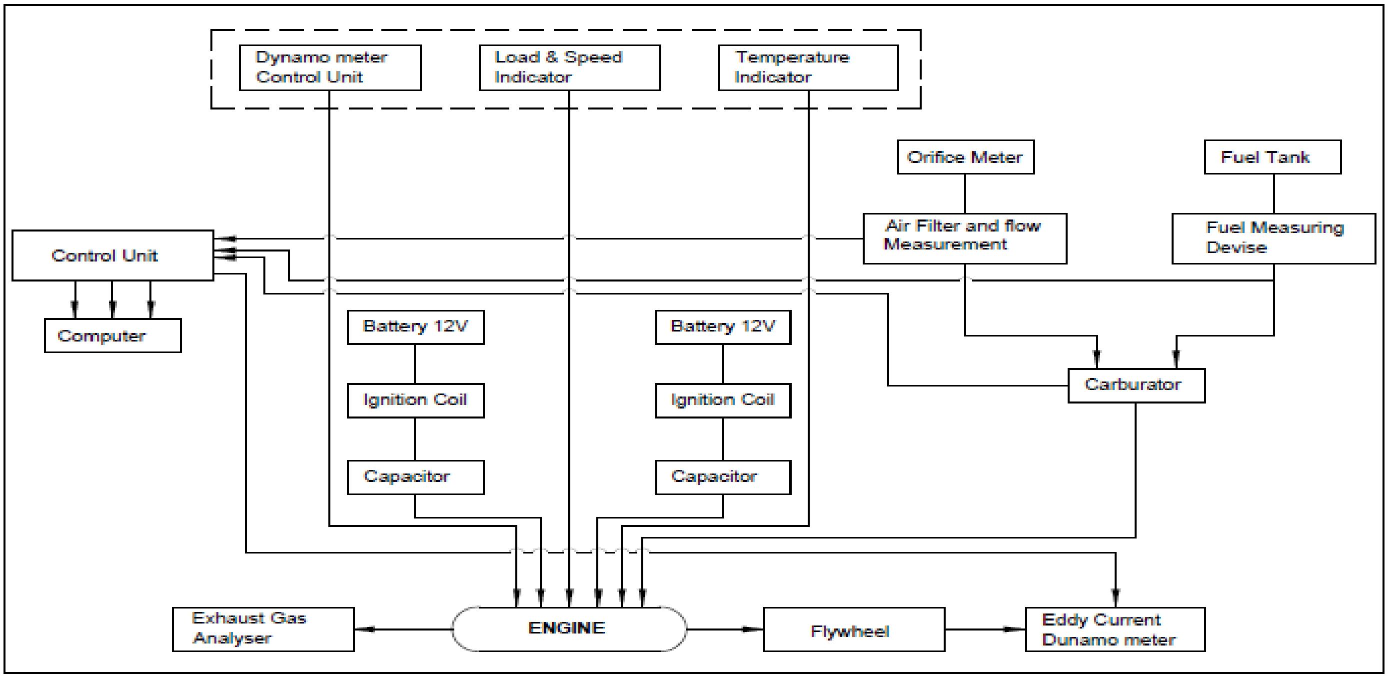

Figure 1: Schematic Diagram of Engine Setup

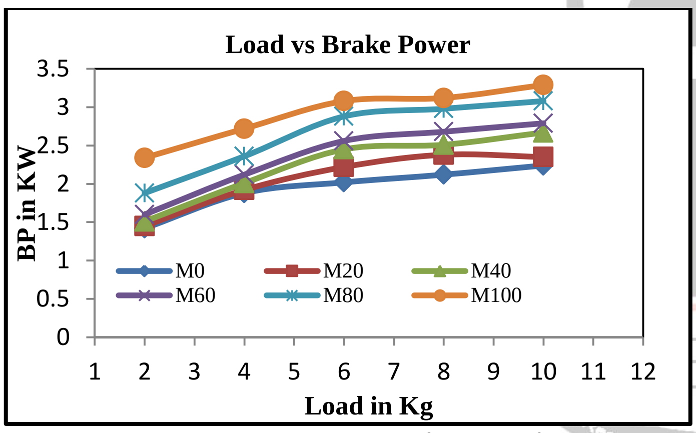

Figure 4: BP with respect to Load at 32° BTDC - 28° BTDC

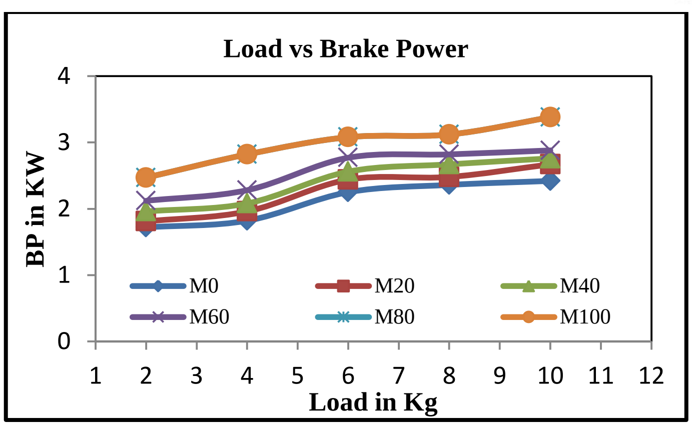

Figure 5: BP with respect to Load at 26° BTDC - 24° BTDC

By comparing the results at different ignition timing combinations, the brake power produced at 26° BTDC – 24° BTDC is slightly higher than the other. The increase in brake power is about 4.3% at the higher load and 2.6% at the lower load. If the spark is initiated at 26° BTDC instead of 32° BTDC, the peak temperature is higher and maximum power will be produced near the TDC instead of generating energy long before TDC.

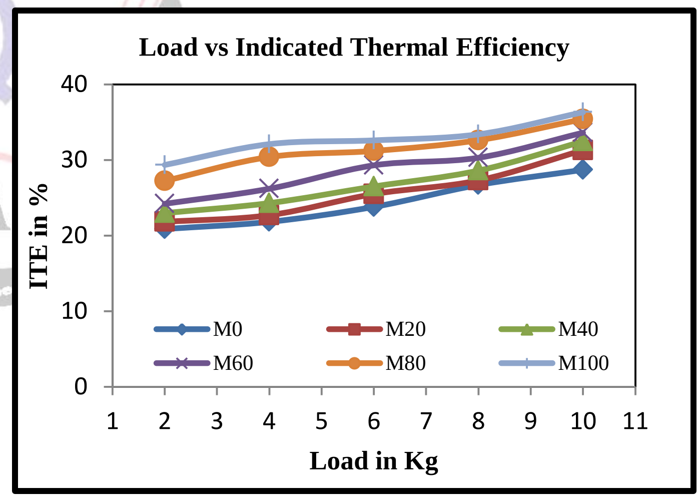

Figure 6: ITE with respect to Load at 32° BTDC - 28° BTDC

The variation of Indicated thermal efficiency with respect to load at different spark ignition timings is labeled in the figure 7 and figure 8. Due to the higher operating temperature and improved combustion, the thermal efficiency is increased by increasing the methanol percentage in the blends. The increase in thermal efficiency at the lower load is about 22% at the lower load and 17.2% at the higher load.

Presence of oxygen and higher octane number in methanol leads to get complete combustion and lesser emission results in higher efficiency.

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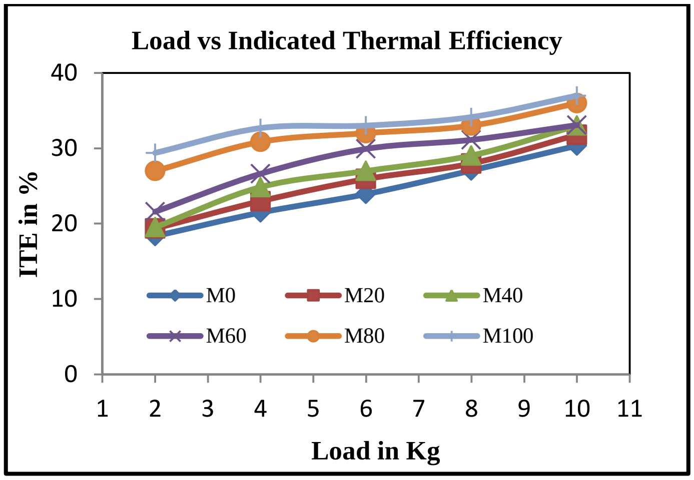

Figure 7: ITE with respect to Load at 26° BTDC - 24° BTDC

The dependence of methanol percentage on brake thermal efficiency at different load conditions is shown in figure 8 and figure 9 respectively. Since the indicated thermal efficiency is increasing by increasing methanol content in blends also increases the brake thermal efficiency.

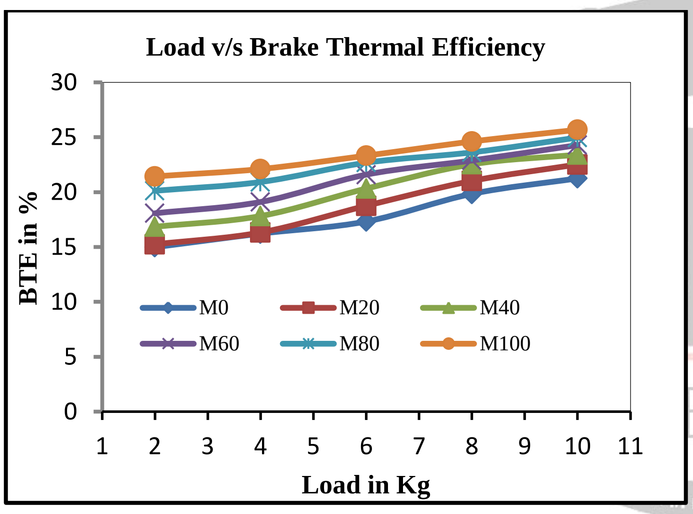

Figure 8: BTE with respect to Load at 32° BTDC - 28° BTDC

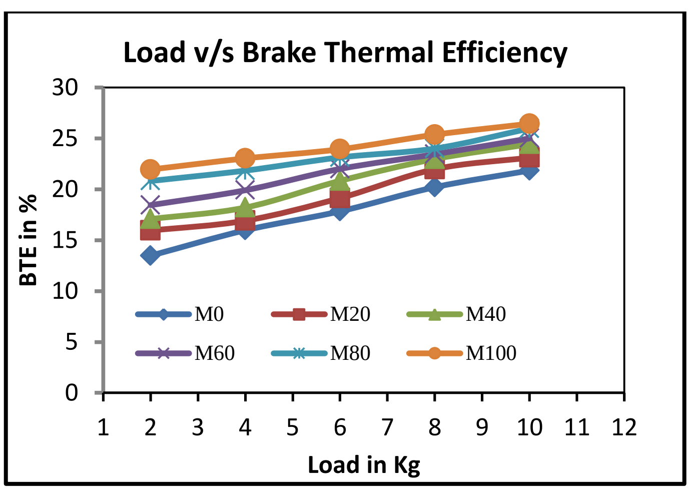

Figure 9: BTE with respect to Load at 26° BTDC - 24° BTDC

B. *Emission Characteristics*

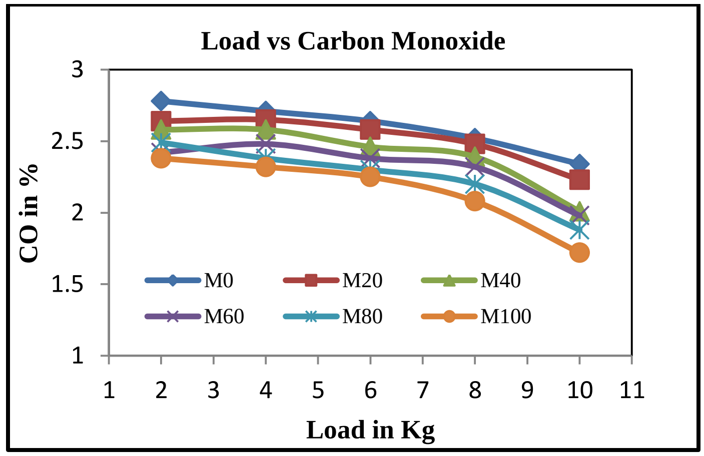

Figure 10: CO with respect to Load at 32° BTDC – 28° BTDC

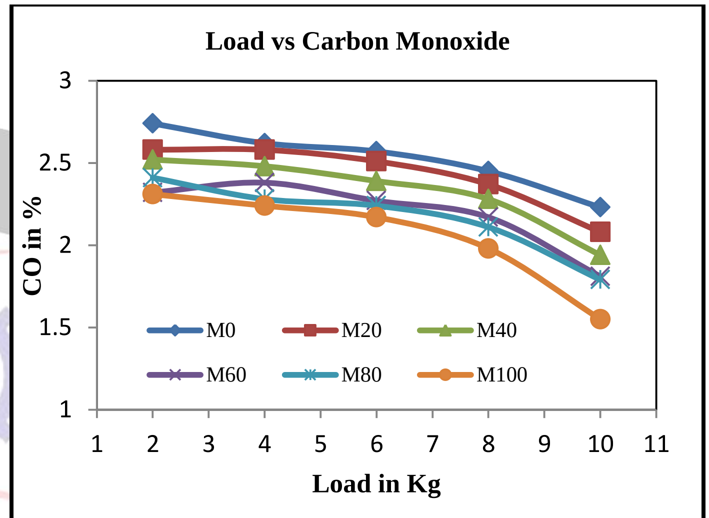

Figure 11: CO with respect to Load at 26° BTDC – 24° BTDC

The variation of carbon monoxide with respect to load at different ignition combination is shown in figure 11 and figure 12 respectively. It is observed that, carbon monoxide emission significantly decreasing by increasing the methanol percentage in the blends in both the combinations. The oxygenated fuel methanol provides more oxygen during the combustion helps in complete combustion converts carbon atoms into carbon dioxide instead of carbon monoxide at the exhaust [12]. The two spark plugs which are placed in the opposite direction creates spark at different time helps in complete combustion thereby reducing the carbon monoxide. By comparing the results in two combinations the 26° BTDC – 24° BTDC shows slightly lesser emission than the other. Higher operating temperature by initiating spark near the TDC can be considered the reason for reduction in CO emission. The reduction in CO is about 36% at the higher load.

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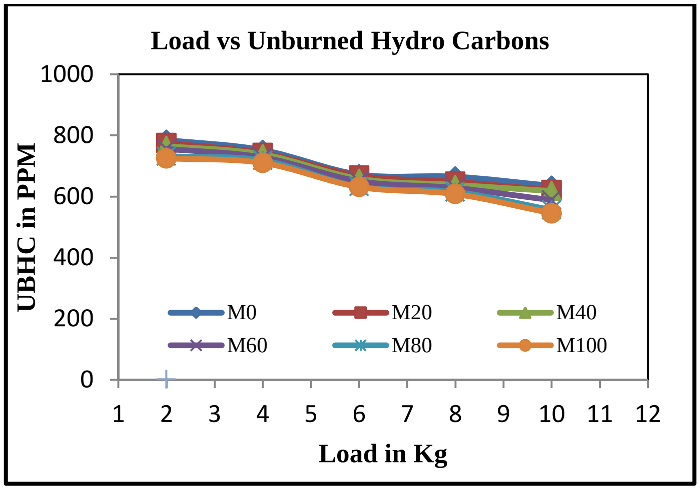

Figure 12: UBHC with respect to Load at 32^o BTDC – 28^o BTDC

The reduction in unburned hydrocarbons at different loads is elaborated in figure 13 and figure 14 for two combinations of spark timings. It can be seen that, emission of UBHC decreases by increasing the methanol content in the blends. This is due to the presence of oxygen atoms in the methanol which helps to improve the combustion efficiency. It is also observed that the emission of UBHC is reduced by increasing the load.

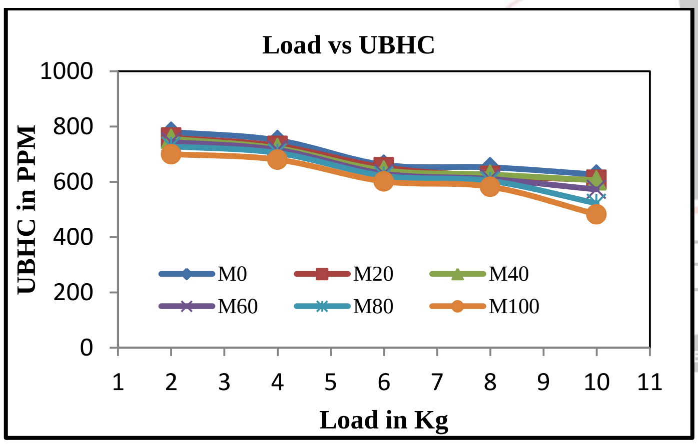

Figure 13: UBHC with respect to Load at 26^o BTDC – 24^o BTDC

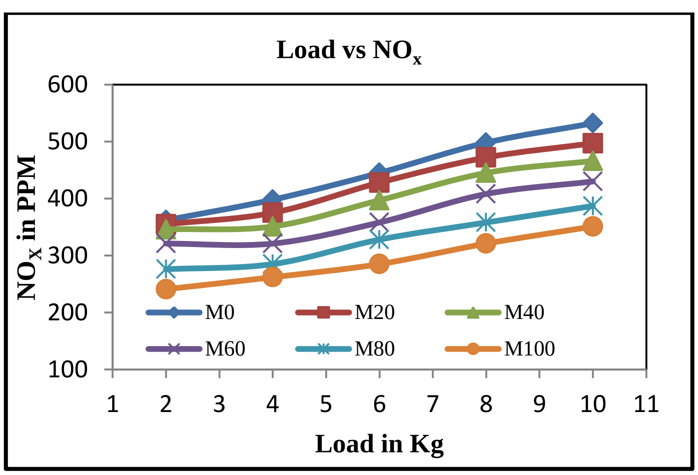

Figure 14: UBHC with respect to Load at 32^o BTDC – 28^o BTDC

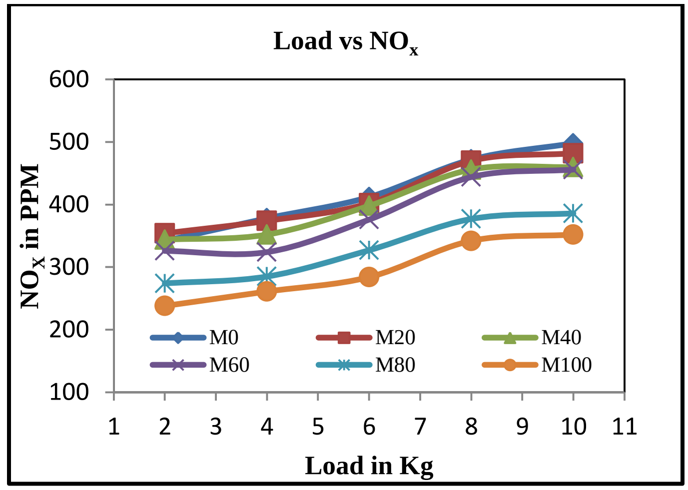

Figure 15: NO_x with respect to Load at 26^o BTDC – 24^o BTDC

The higher operating temperature at the higher load can be a reason for decreasing the emission of unburned hydro carbons. By comparing the results obtained in the two combinations of spark timings, 26^o BTDC – 24^o BTDC showed better results than the other. The oxides of nitrogen is reducing by increasing the methanol quantity in the blends under 32^o BTDC – 28^o BTDC and 26^o BTDC – 24^o BTDC combinations can be observed in the figure 14 and figure 15 respectively. The NO_x is increasing by increasing the load in both the cases. However I t is showing decreasing trend by increasing the methanol percentage in blends. The reduction in NO_x is about 33% at the lower load and about 34.56% at the higher loads. The presence of oxygen in methanol can be a reason for getting this decreasing trend [13]. The increase in NO_x at the higher loads is due to the higher operating temperature. By comparing the results in figures, both the spark ignition combinations are showing almost same values.

IV. CONCLUSION

In this study, the effect of methanol on performance and emission characteristics of 4 stroke single cylinder digital twin spark ignition engine is experimented for two ignition combinations such as 32^o BTDC – 28^o BTDC and 26^o BTDC – 24^o BTDC. The experimental results revealed that, there is significant reduction in CO, UBHC and NOx with increase in thermal efficiency. By comparing the results obtained at different combinations of ignition timings, 26^o BTDC – 24^o BTDC showed better results than the other. The fuel consumption is increasing by increasing the methanol percentage in blends. However this is recovered by increasing the thermal efficiency and reduction in emission.

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