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This article presents experimental results of the effect of methanol gasoline blends as alternate fuels for the spark ignition (SI) engine. As the cost of the gasoline is periodically increasing the quest for the alternative fuels are evolved with which the emissions are reduced along with improved engine performance. A set of experiments have been conducted to investigate the effect of gasoline methanol blends in methanol percentages of M5, M10 and M15 on the engine performance and emissions. A significant reduction in emissions is observed with methanol blends compared to the standard gasoline with improved engine performance and emission characteristics. The fuels blends ranging from M10 to M15 have been found suitable for reduced emissions and improved engine performance.

Keywords: methanol; gasoline; alternate fuels; blends; SI engine

1. Introduction

From the history of the automotive sector, the automotive vehicles is run by the fossil fuels (Tiwari 2011). These fossil fuels are found within the top layer of the earth crust and gives the output as pollution with little efficiency of the engine (Kodah et al. 2000). Some of the factors by using the gasoline as fuel are summarised as follows:

(1) The environmental impact of using the present hydrocarbon fuels. This manifested itself in several ways such as global warming, acid rains and greenhouse effect.
(2) The increased demand for energy as a result of the population growth and technological development in the world. This laid heavy stress on the conventional reserve of fossil-based fuels to meet this demand.
(3) The increasing cost of energy sources (Badran and Yamin 2004).

The rapid growth of the world's crude oil reserves and the environmental considerations has focused on the clean, renewable, and sustainable and non-petroleum fuels. Methanol, known as methyl alcohol, has also been used as an alternative fuel for automotive engines. Recently, its excellent combustion properties have made it the strongest choice of the automotive industry as well (Liao et al. 2006).

The energy content of methanol is less than that of gasoline so that higher fuel consumption would be theoretically predicted for blends of methanol and gasoline than for straight gasoline. However, these blends will burn more satisfactorily at sub-stoichiometric fuel to air ratios than will gasoline, and this fact together with their better anti-knock qualities and cooler, more efficient engine operation may offset this theoretical prediction. Depending on the automobile engine tested, fuel economy has been shown to improve slightly or decrease slightly by the addition of methanol to form blended fuels. This increase is generally reported, and might be economically important depending upon the comparative prices of gasoline and methanol (Kowalewicz 1993).

2. Methanol production

The raw materials for methanol production are coal and remote natural gas; these may all be carbon-containing materials, such as residual oil, shale, peat, tar sands and waste. Methanol is produced in two steps. In the first step, synthetic gas (H_2+ CO) is produced by reaction of gasified raw material with steam at high temperature. In the second step, methanol is produced from compressed (50–200 bar) synthetic gas by a catalytic process (copper-based catalyst). The energetic efficiencies of methanol production are as follows:

- from natural gas 60–65%,
- from coal 47–52%,

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- from biomass 42–52%,

and is higher than that of gasoline (methanol-to-gasoline process and Fischer–Tropsch's method) and of diesel oil (Fischer–Tropsch's method). The costs of methanol (produced from coal) and gasoline in the United States and Germany are nearly the same; that of methanol is a little higher but could be lowered by mass production (Cassady 1887).

2.1. *Physical properties of methanol*

Methanol is a clear, low viscosity liquid with a faintly sweet odour at low concentrations in air. Chemically, methanol is an aliphatic alcohol containing about 50 wt% oxygen with physical properties consistent with other alcohols used as gasoline blending components:

Typical composition (wt%): Carbon 37.5
Hydrogen 12.6
Oxygen 49.9
Molecular weight (kg/kmol): 32.042
Melting point (°C): −97.6
Boiling point (°C): 64.6
Flash point (closed cup, °F): 52 (as per API data book).

Methanol used as an additive or a substitute for gasoline can immediately help to solve both energy and air pollution problems (Gravalos et al. 2011). Pure methanol as a fuel shows that methanol burns more energy efficient at leaner air–fuel ratios, and at higher compression ratios without detonation than commercial gasoline (Richard et al. 1976). With the addition of methanol to gasoline, the fuel economy and thermal efficiency are improved (Wei et al. 2008). The reduction in emissions takes place when methanol is used with high blends and also in pure form (Gravalos et al. 2013).

The performance and emission characteristics of the spark ignition engine running on methanol blended with gasoline were evaluated and compared with neat gasoline fuel. In the present investigation, the performance and emission characteristics were carried out on four cylinder, four-stroke carburettor-type spark ignition (SI) engine by carrying out the experiments using gasoline and gasoline methanol blends to study the behaviour of the engine on the use of alternative fuels.

2.2. *Engine and its specifications*

The investigation is carried out by using four cylinder, four-stroke carburettor-type Hindustan SI engine. Its specifications are four stroke, four cylinder, SI,

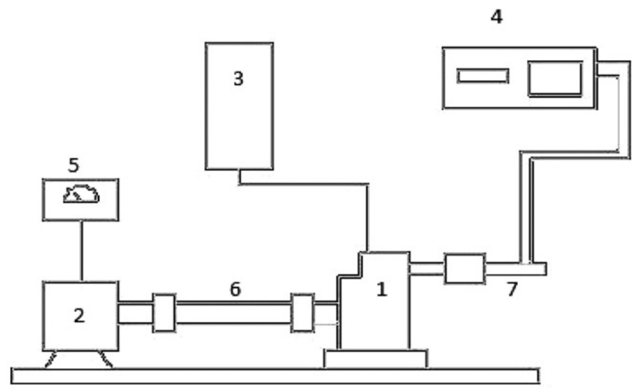

Figure 1. Schematic diagram of the experimental set-up.

water-cooled carburettor-type Hindustan SI Engine, which are as shown in Figure 1: rated power: 17.5 HP, bore: 73.02 mm, stroke: 88.9 mm and rated speed: 1500 rpm.

2.3. *Testing procedure*

A four cylinder, four-stroke carburettor-type SI Hindustan engine is coupled to water brake dynamometer of Froude Patent Hydraulic dynamometer, England. With the help of coupling and mounted to a rigid frame having provision of measuring speed, fuel measuring tube and a gas analyzer, it can measure five gases, namely CO, CO_2, NO_x, HC and O_2 (NETEL) for measuring the tail pipe emissions. The ignition system consists of conventional high tension coil and spark plug arrangement with the primary coil circuit operating on contact breaker in the distributor.

A series of experiments were carried out using gasoline and various methanol blends of 5%, 10% and 15% on volume basis (methanol percentage to gasoline). The test blends were prepared just before starting the experiment to ensure that the fuel mixture was homogeneous. The engine was started and allowed to warm up for a period of 20–30 min. Before running the engine with a new fuel blend, it was allowed to run for sufficient time to consume the remaining fuel from the previous experiment.

All the blends were tested under constant speed conditions. The required engine load was obtained through the dynamometer control. The engine speed, fuel consumption, load and engine emissions were measured. After the engine reached a stable working condition (steady state), emission parameters such as CO, CO_2, HC and NO_x from an exhaust gas analyzer were recorded.

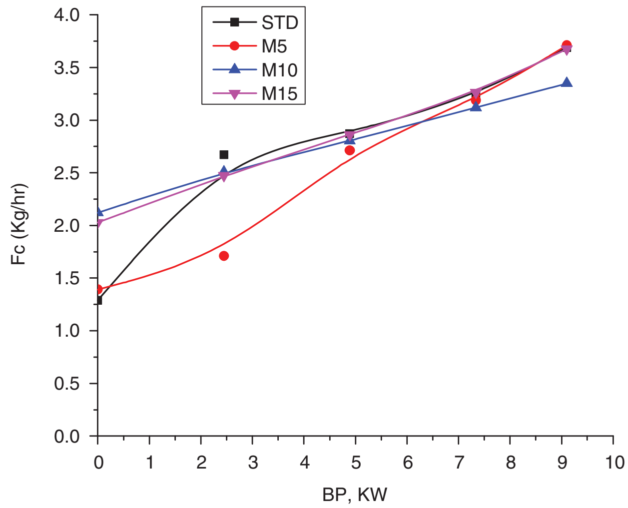

Figure 2. Variation of fuel consumption with brake power.

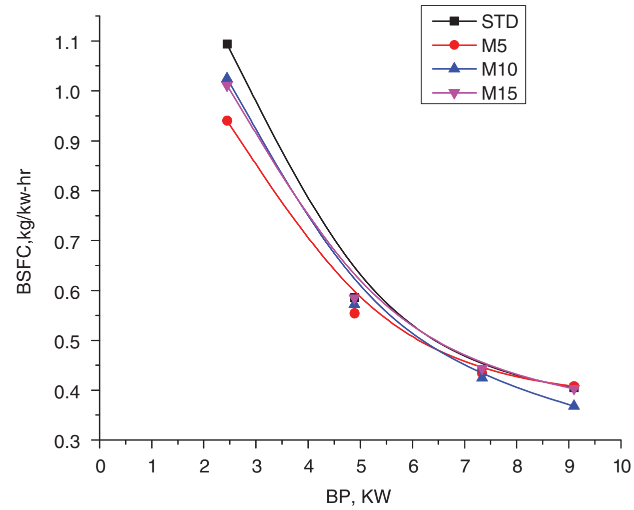

Figure 3. Variation of BSFC with brake power.

3. Results and discussion

3.1. *Part I*

The results of experiments conducted using pure gasoline and methanol gasoline blends are presented here with respect to brake specific fuel consumption (BSFC), brake thermal efficiency and emissions.

From Figure 2, it is observed that for M5 the fuel consumption is less up to the part load operation as the brake power increases compared to the gasoline and gasoline methanol blends, but for M10 as the brake power increases the fuel consumption is increased up to the part load and at full load operation the fuel consumption reduces compared to other gasoline and methanol gasoline blends.

The effect of methanol addition to gasoline on BSFC is shown in Figure 3. It can be seen that the BSFC decreased as the methanol percentage increased and M5 has shown lowest BSFC up to part load and it slightly increased at full load compared to other fuel blends. All methanol blends have shown decreasing BSFC values compared to standard pure gasoline. BSFC values using M5 are consistent throughout the experiment and are significantly low with all engine operations.

From Figure 4, it is observed that the part load brake thermal efficiency of the fuel M5 is high compared to all other fuels and at full load the blend M10 is comparatively high. This may be attributed to the availability of fuel bound oxygen in the blend which ensured complete combustion and high rate of heat release. The brake thermal efficiency of the blends M10 and M15 are consistent and stable throughout the experiments. Ambarish, Achin Kumar, and Bijan Kumar (2012) have reported that the fuel consumption

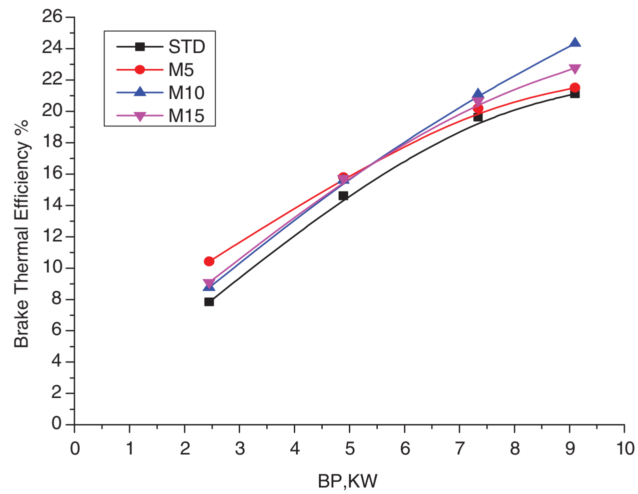

Figure 4. Variation of brake thermal efficiency with brake power.

and brake thermal efficiency of the methanol blends ranging from M10 to M40 have shown similar trends as observed in this experiment.

3.2. *Part II*

A discussion has been given below based on the tail pipe emissions of the experiments conducted.

By comparing Figures 5 and 6, the CO values for gasoline are 3.98%, and 3.25%, 2.18%, and 0.84% for M5, M10 and M15, respectively, and it can be observed that for M5 blend, the percentage of reduction is 18.3 whereas for M10 and M15 they are 45.22% and 78.89%, respectively, compared to pure gasoline at

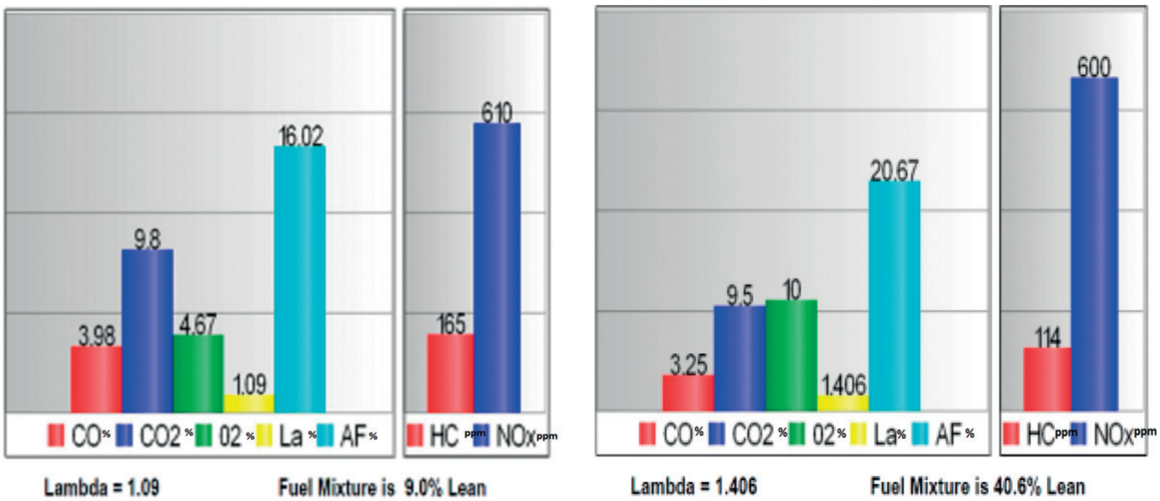

Figure 5. Effect of gasoline and M5 blends on exhaust emissions at full load.

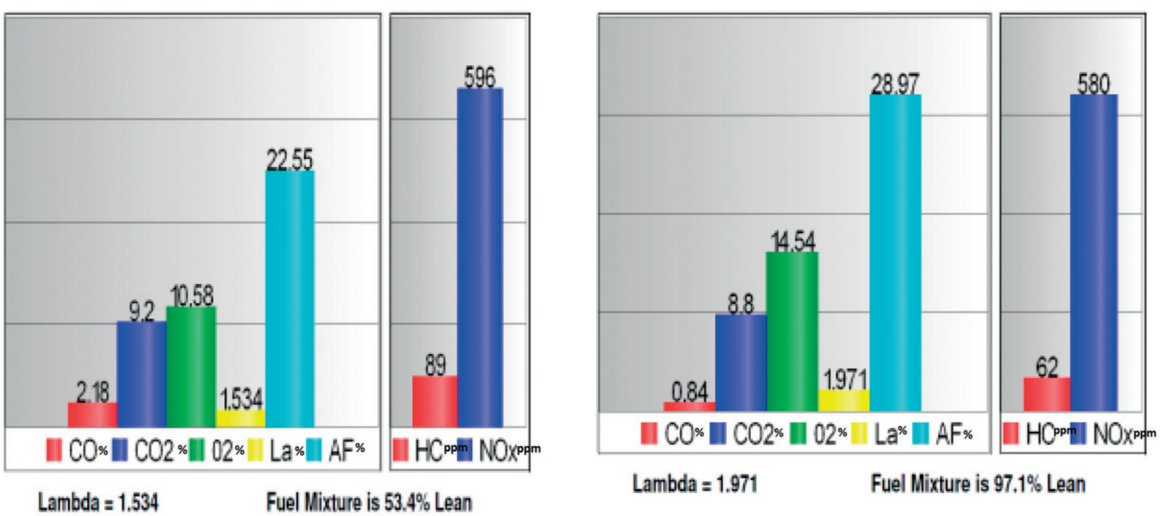

Figure 6. Effect of M10 and M15 blends on exhaust emissions at full load.

the full load operation of the engine. The CO_2 values for gasoline are 9.8% whereas 9.5%, 9.2% and 8.8% for M5, M10 andM15 blends, respectively. The percentage reduction for the M5, M10 and M15 are 3.06%, 6.12% and 10.20%, respectively, compared to pure gasoline at the full load operation of the engine. The HC value for gasoline at full load is 165 ppm and for M5, M10 and M15 are 114 ppm, 89 ppm and 62 ppm, respectively. It is observed that for M5 the percentage reduction is 30.90% whereas for M10 and M15 are 46.06% and 62.42%, respectively. The NO_x value for the pure gasoline at full load is 610 ppm but for M5, M10 and M15 blends are 600 ppm, 596 ppm and 580 ppm, respectively. By observing the percentage reduction of the same blends, they are 1.63%, 0.65% and 4.19% for M5, M10 and M15, respectively. On the basis of the above experimental observations, it can be concluded that the gasoline methanol blends between M10 and M15 can be used comfortably without any modification to the engine to improve the performance and to reduce the tail pipe emissions.

From Figure 7, the unburned hydrocarbons concentration are maximum for pure gasoline and by increasing the methanol percentage from M5 to M15 the hydrocarbon emissions are decreased. This is because of the improved octane number of the blended fuels which contributed to the complete combustion of

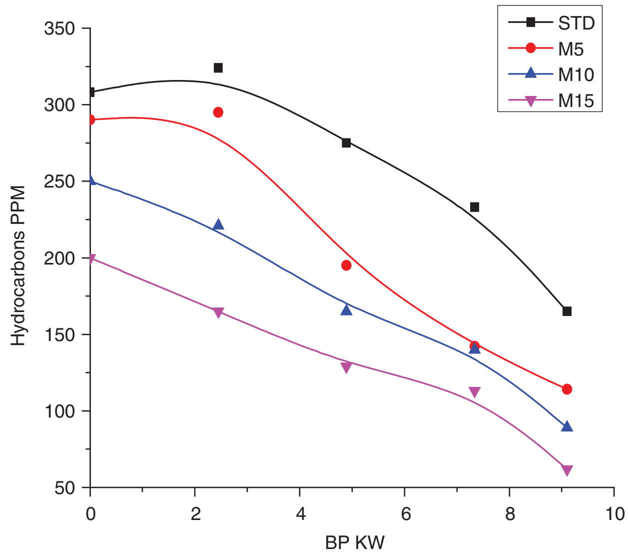

Figure 7. Variation of hydrocarbons corresponding to the brake power.

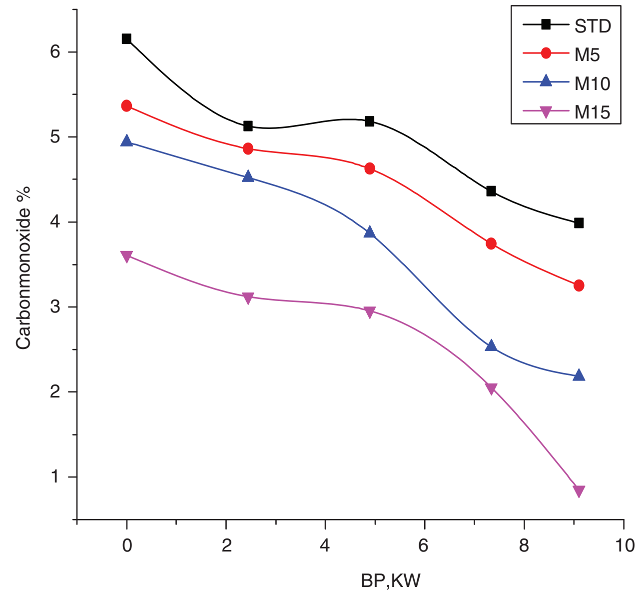

Figure 9. Variation of carbon monoxide corresponding to the brake power.

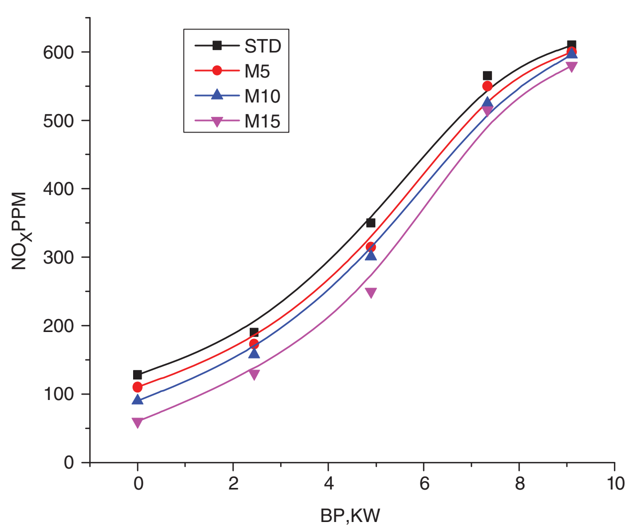

Figure 8. Variation of NO_X corresponding to the brake power.

fuel thus reducing the HC emissions. M15 gives the minimum hydrocarbon emissions compared with other pure gasoline and gasoline methanol blends.

From Figure 8, it can be observed that the NO_x emissions are measured as 610 ppm when pure gasoline is used as fuel and it is 580 ppm for M15 being the lowest in all sets of experiments. All the methanol blends have shown reduced NO_x emissions compared to the pure gasoline fuel. It has been observed NO_x increases gradually up to full load with all the blends but as the methanol concentration increases the NO_x decreases and minimum NO_x is observed for the M15 blend.

Figure 9 shows the variation of carbon monoxide emission with brake power. It can be clearly seen that with pure gasoline operation the CO emissions are significantly high compared to all the other gasoline methanol blends at all engine loads. It has also been observed that the CO emissions are high at no load and followed a decreasing trend as the load increased. Addition of methanol in gasoline in different proportions up to M15 has led to the decrement of CO emissions as the fuel bound oxygen in the methanol blends ensured complete combustion. For M15 blend, the CO percentage is very low compared to other blends and gasoline fuel at the no load and as the load on the engine is increased with M15 blend diminution is observed at the full load.

From Figure 10, it is seen that for the standard no load conditions the air–fuel ratio is high and as the load increased the air–fuel ratio decreased. As the methanol percentage increases for M5 at part load the air–fuel ratio increases, and to the full load the minimal air–fuel ratio is detected and for M15 the air–fuel ratio at no load increases and as the load on the engine increases reduction is observed at part load and at full load it increases.

From the above observations of the emission results, it is seen that CO, CO_2, HC and NO_X decrease

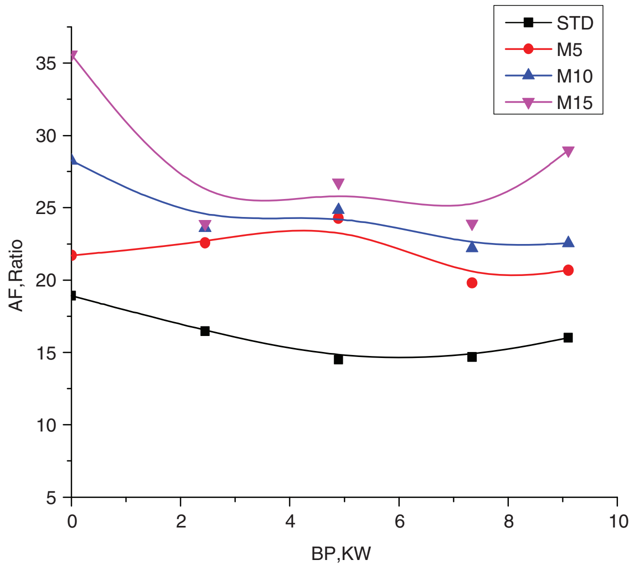

Figure 10. Variation of air–fuel ratio with brake power.

from the pure gasoline test to M15 blends but the air–fuel ratio and O_2 increase, hence the emissions are low.

4. Conclusion

In this work a four cylinder four-stroke carburettor-type Hindustan SI engine was utilised. Experiments were conducted at steady-state condition by preparing the blends just before the starting of the experiment. The main experimental results are summarised as follows:

- For M10 the BSFC is decreased gradually compared with other standard and blends.
- Higher brake thermal efficiency is observed for M10 fuel compared to other blends.
- From the experimental observations, M15 has shown lower emissions compared to other blends.
- As the blend concentration in the gasoline increases the tail pipe emissions are reduced.
- It is noticed that the air–fuel ratio of the engine when run using M15 is higher compared to other fuel blends.

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