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The effect of ignition timing and methanol gasoline blends on the performance and emissions of the spark ignition engine

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The automobile has changed a lot since the first horseless carriage to the gasoline-powered vehicles. The automobile has changed when the roads became paved and the fuel consumption in the gasoline engine forms a major portion of total petroleum consumption in the automobile industry. This work interweaves the study of experiments on the four-cylinder carburettor-type gasoline engine to cue the performance and emission characteristics by advancing the ignition timing from 10° to 30° BTDC using gasoline methanol blends as fuels in the ratios of 5% to 15% at an interval of 5% on volume basis. The effects of varying the engine working parameters such as ignition timing, brake power, brake thermal efficiency are observed and the variation of different engine emission parameters with the exhaust gas analyser is also observed. For M5, the brake-specific fuel consumption values decreased and brake thermal efficiency increased For M15, exhaust emission values decreased.

Keywords: gasoline engine; methanol; ignition timing

1. Introduction

Four-stroke spark ignition (SI) engine was developed by Otto in 1876. This engine provided power output of 3 HP. Since then, the development of engine has been done continuously over 100 years. Even now, some engines can provide power output of more than 1000 HP (Sitthiracha, Patumsawad, and Kpetniyom 2006).

The development of the SI along 100 years has been very slow due to some parameters such as valve timing, ignition advance, compression ratio, combustion characteristics, etc., by influencing the performance of the engine. And also, there is increase in the cost of petroleum fuels. Using the gasoline as a fuel for the SI engine, some problems still exist.

- It is impossible to control or to develop the homogeneous mixtures with standard specifications.
- To meet the octane requirements of unleaded gasoline, more of dense aromatics have to be produced in catalytic reformers, which leads to increased density of unleaded gasoline which causes problems with mixture formation, combustion, and emissions (Badran and Yamin 2004).

The suggested solutions to circumvent the problem could be categorised into two basic approaches:

- Exploring for new alternative fuels.
- Advancing the ignition timing.

1.1. The effect of methanol

Methanol is a clean burning, high octane blending component for gasoline that is made from alternative non-petroleum energy sources such as natural gas, coal, and biomass (Methanol n.d.). Methanol has many fuel properties that promote cleaner burning in gasoline engines. It has a better lower boiling temperature for better fuel vapourisation in cold engine operation. There are several benefits of using the methanol than the gasoline as an alternative fuel such as lower emissions, high performance, and very lower risk of flammability (Alternative Fuels Data Center: Methanol Benefits. n.d. 2006) and operate at leaner air fuel ratios and at higher compression ratios without detonation (Methanol as an automotive fuel n.d).

Methanol has a significant effect on the performance of the gasoline engine. The best engine performance (within the range studied) for maximum power output and minimum brake-specific fuel consumption (BSFC) occur when a mixture of 15 volume percent methanol and 85% gasoline blend are used. Methanol engines burn cleaner and more efficiently, which increases with increasing mileage of the vehicle. (Kowalewicz 1993). Hu et al. (2007) studied the combustion and emission characteristics of a methanol/gasoline-fuelled engine and concluded that the hydrocarbon (HC) is reduced to about 40% at 5°C and to 30% at 15°C during the cold-start and warm-up period; CO is reduced to nearly 70% when the engine is fuelled with M30. Comparing the methanol and gasoline lower boiling

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Table 1. Engine specifications.

Make	Hindustan
Number of cylinders	4
Rated power	17.5 HP
Bore	73.02 mm
Stroke	88.9 mm
Cooling medium	Water
Rated speed	1500 RPM

Table 2. The main features of dynamometer.

Type	Froude patent hydraulic dynamometer
Maximum load	36 lb
Maximum BHP	150

point, flame propagation speed, high oxygen contact, and the simple chemical structure of methanol gives rise to a the reduction of CO and HC (El-Emam and Desoky 1985; Bata and Roan 1989; Rice et al. 1991; Liu et al. 1998, 2007; Zervas, Montagne, and Lahaye 2003; Abu-Zaid, Badran, and Yamin 2004).

1.2. The effect of ignition advance

The efficiency of a spark-ignited engine can be increased by using information from the combustion to control the spark advance. The peak pressure position of the in-cylinder pressure trace is a parameter that indicates how efficient the spark advance is (Eriksson 1999).

Ignition advance is the condition when ignition of fuel occurs earlier than the correct ignition timing. Ignition of mixture takes place near the end of compression stroke. If the ignition is advanced, it means fuel–air mixture will burn too early before the end of the compression stroke. In this case, the crank and connecting rod will have to push the piston in order to compress the gases (Timings and retard n.d.). Advancing the spark increases the knock severity or intensity and retarding the spark decreases the knock (Combustion In SI Engines n.d.). In a direct-injection SI methanol engine, a non-uniform mixture with a stratified distribution can be formed, having optimal injection and ignition timings to obtain a good combustion and low exhaust emissions in the overall mode range. Both methanol injection timing and ignition timing have a significant effect on methanol engine performance, combustion, and exhaust emissions (Li 2010).

2. Experimental apparatus and equipment

2.1. Engine equipment

In this study, the experiments are performed on the carburettor-type four-stroke four-cylinder Hindustan SI engine. The engine specifications are given in Table 1.

The engine is coupled with the hydraulic dynamometer and it has the provision of setting the ignition timing. This dynamometer has the provision of mechanical linkages for the purpose of loading the engine (Table 2). The fuel consumption rate is measured by the arrangement of burette and the stopwatch for 10 cc. The exhaust emission, which is HC, CO, CO_2, and NO_x, is measured by the multi-gas analyser (NETEL). The performance and exhaust emissions are measured in the laboratory premises in the mechanical engineering department. The pictorial representation is shown in Figures 1 and 2.

Figure 1. The pictorial representation of the experimental set-up.

Figure 2. The pictorial representation of variation of the ignition timing.

2.2. Experimentation procedure

The engine was started and allowed to warm up for some time and the experiments were carried out using different blends such as M5, M10, and M15 with standard test using gasoline. At the same blending proportions, the timings were also changed from 10°, 20°, and 30° ignition timing advancement. Before running the engine to a new fuel blend, it was allowed to run for a sufficient time to consume the remaining fuel from the previous experiment.

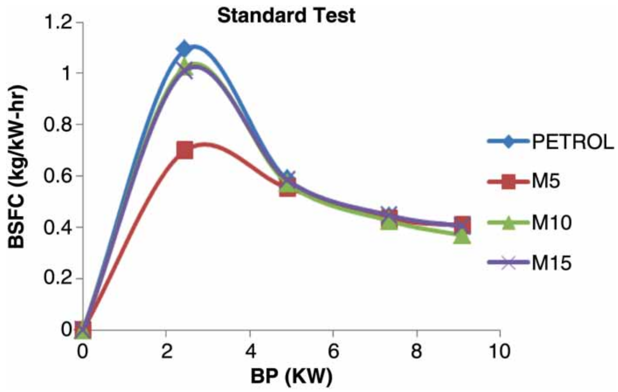

Figure 3. Variation of the BSFC with brake power.

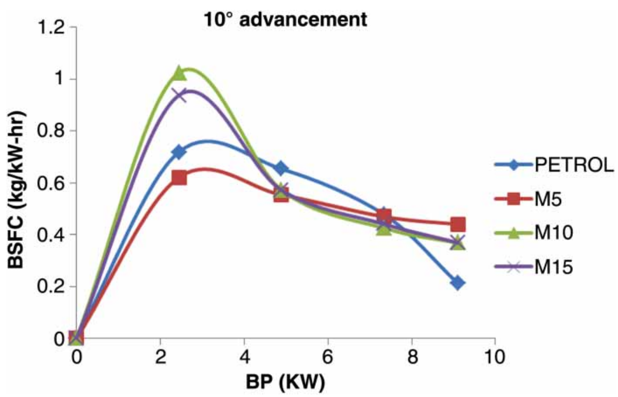

Figure 4. Variation of the BSFC with brake power at 10° advancement.

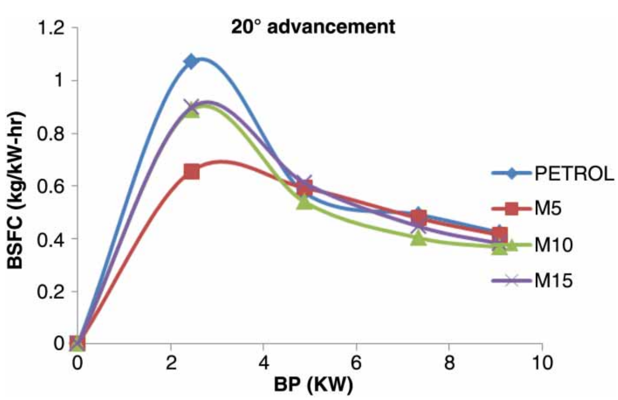

Figure 5. Variation of the BSFC with brake power at 20° advancement.

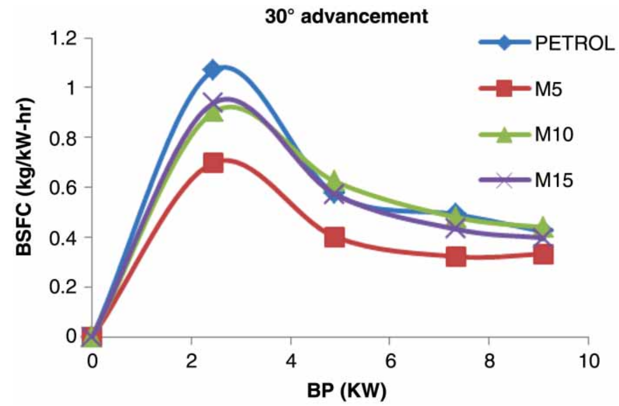

Figure 6. Variation of the BSFC with brake power at 30° advancement.

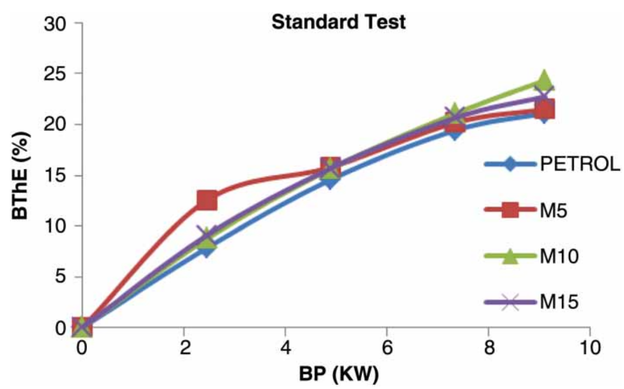

Figure 7. Variation of brake thermal efficiency with brake power at standard test.

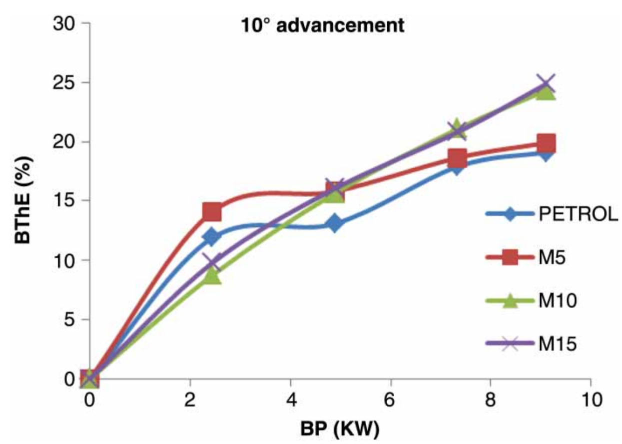

Figure 8. Variation of brake thermal efficiency with brake power at 10° advancement.

3. Results and discussions

3.1. Brake-specific fuel consumption

The BSFC is defined as the ratio of mass of fuel consumption to the brake power. The BSFC values of different fuels are illustrated in Figures 3–6, respectively, at different ignition timings. It can observed from the figure that the BSFC is lower for M5 at standard 10° and 20° timings compared with other fuels up to part load operation of the engine and it is found to be low even at full load at 30° ignition advance. M10 and M15 are found to have significantly lower BSFC values at all engine loads compared with that of other fuels at all ignition timings. This is attributed to the availability of fuel-bound oxygen molecules which ensured the completeness of combustion resulting in lower fuel consumption.

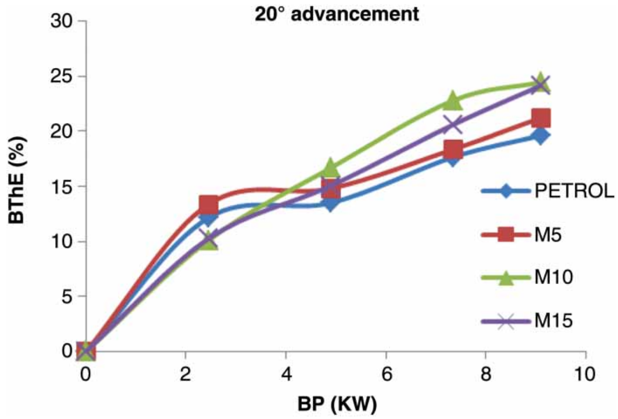

Figure 9. Variation of brake thermal efficiency with brake power at 20° advancement.

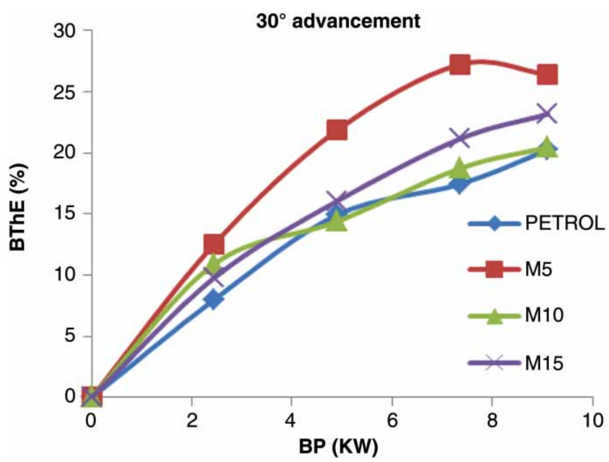

Figure 10. Variation of brake thermal efficiency with brake power at 30° advancement.

3.2. Brake thermal efficiency

Brake thermal efficiency of the engine when run at different ignition timings and with different fuels is shown in Figures 7–10. As it can be seen from Figures 7–10, brake thermal efficiency for the gasoline methanol blends from M5 to M15 is improved compared with that of standard engine operation at all ignition timings. And as the percentage of blend increased, the brake thermal efficiency is also found to be increase. At 30° ignition timing, blend M5 resulted in higher brake thermal efficiency compared with that of other blends because of higher combustion rate due to ignition advance. The molecular oxygen in the fuel is also believed to have contributed to the higher combustion rate since the heating value of the fuel is very near to that of the standard gasoline for M5. For other blends, as the percentage of methanol increased, the heating value of the fuel is decreased but the rate of combustion is much superior to that of standard gasoline and results in higher brake thermal efficiencies.

Variation of exhaust emissions at different ignition timings at full engine load operation with mixture quality percentage is shown in Figures 11 and 12. At full engine load, the higher rate of fuel air charge is inducted into the cylinder to accommodate the rise in requirement of brake power to overcome the load applied resulting in faster completion of combustion cycle. When methanol blends are used as fuels, the lower heating values prompted more fuel air charge to be sucked than the normal. Because of faster completion of combustion cycle, the characteristic advantage of fuel-bound oxygen is not found to have helped the complete combustion. But the advanced ignition timing has contributed to the maximum possible completeness of combustion at the prevailing in-cylinder conditions and resulted in lower exhaust lean fuel mixtures. Figures 13 and 14 show the variation of CO emissions at different ignition timings with different fuels. It is noticed that the CO emissions are reduced as the percentage of methanol content is increased in the blend. The higher combustion rate of blends resulted in complete combustion and produced lower CO emissions at all ignition timings.

Variation of NO_x emissions with brake power is shown in Figures 15 and 16. The lower heating value of the

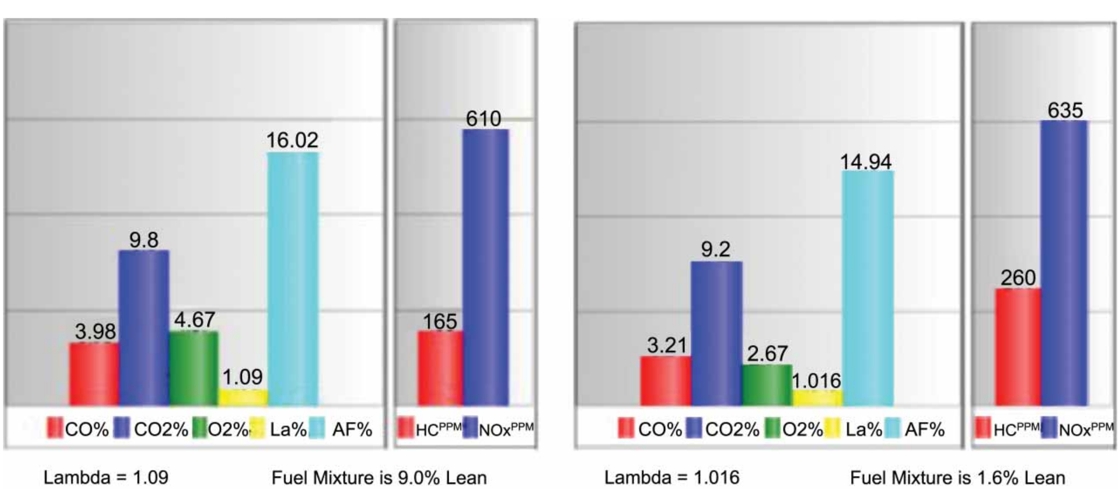

Figure 11. Variation of exhaust emissions at full load on standard and 10° advancement with base fuel.

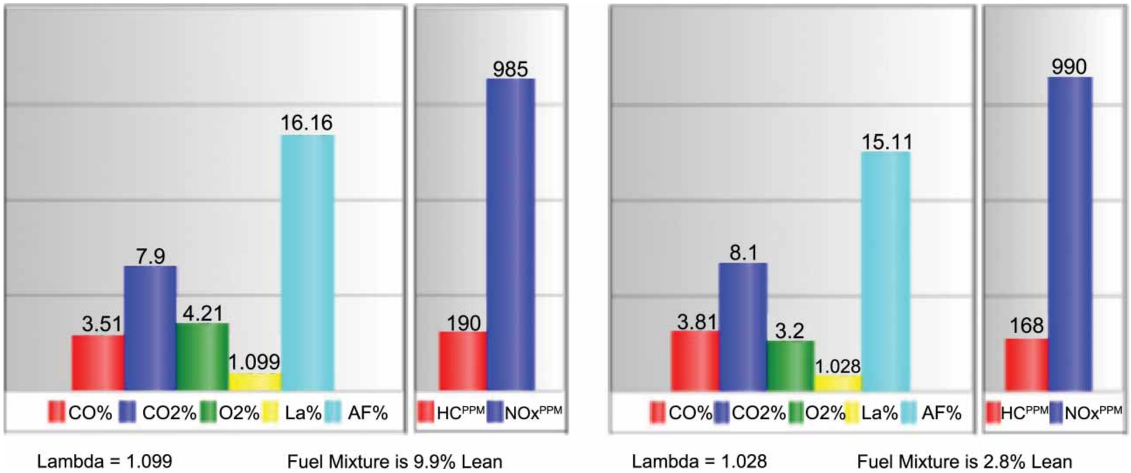

Figure 12. Variation of exhaust emissions at full load 20° and 30° advancement with base fuel.

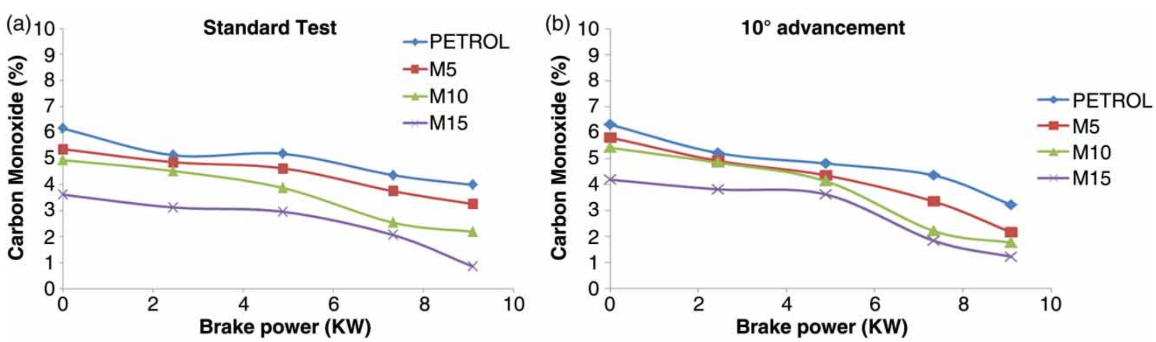

Figure 13. Variation of CO with brake power at standard and 10° advancement.

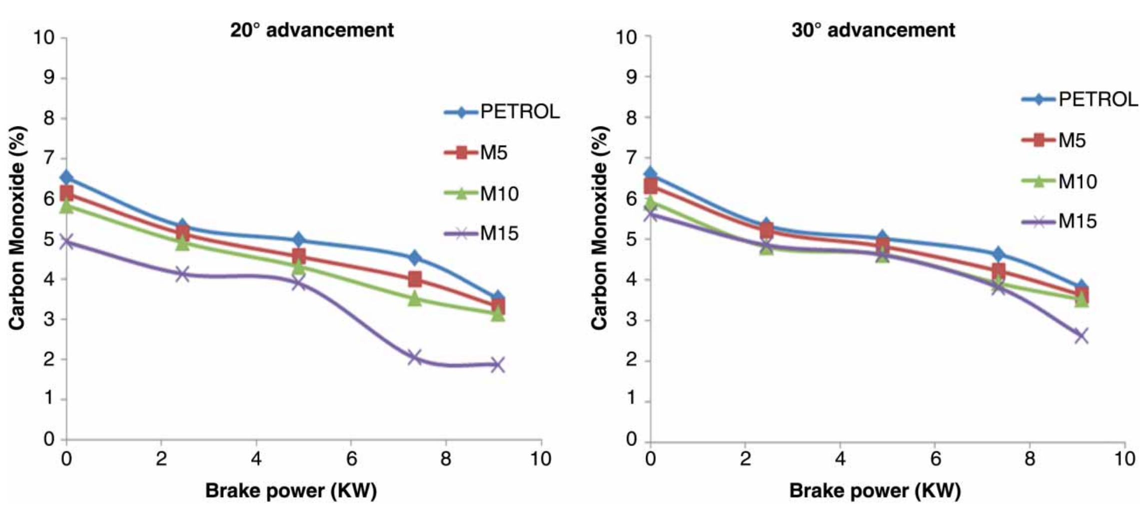

Figure 14. Variation of CO with brake power at 20° and 30° advancement.

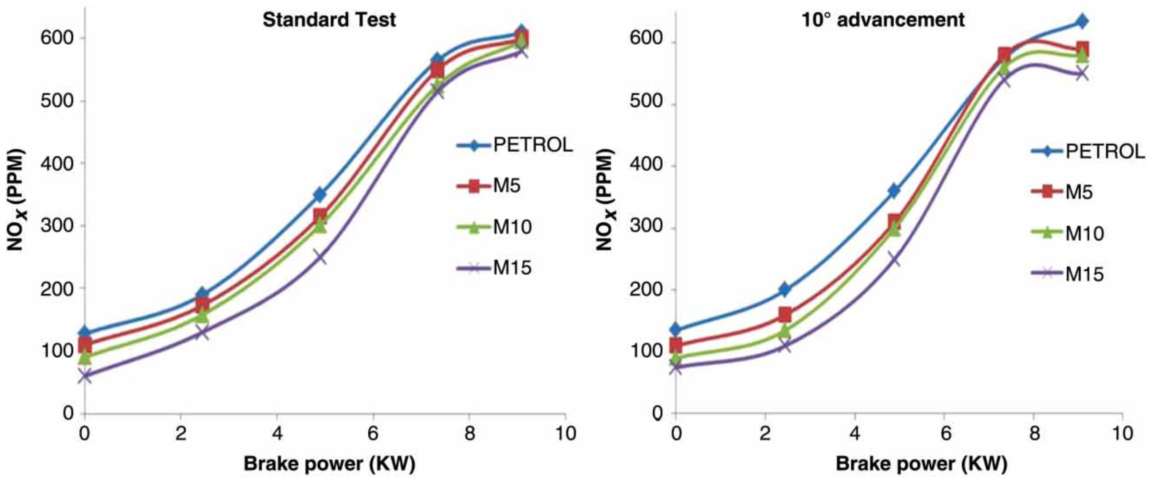

Figure 15. Variation of NO_x with brake power at standard and 10° advancement.

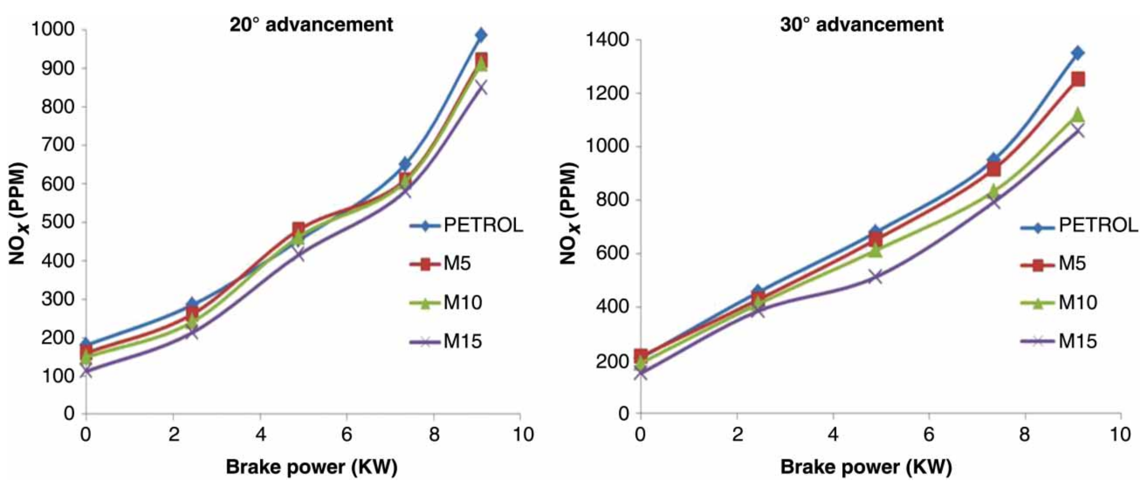

Figure 16. Variation of NO_x with brake power at 20° and 30° advancement.

methanol blends are believed to have produced lower gas temperatures inside the cylinder during the combustion process resulting in lower NO_x emissions since the NO_x emission is majorly prompt or thermal NO_x. It has been observed from the investigation that the pure gasoline produced higher NO_x than that of other fuels at all ignition timings.

4. Conclusions

In this work, a four-stroke four-cylinder Hindustan-motors-made-carburettor-type SI engine was used to carry out the investigations. Experiments were conducted at steady-state condition and the blends are prepared just before the start of the experiment. Ignition timings are varied from standard timing of 7° to 10°, 20° and 30° advancing. The main experimental results are summarised as follows.

- It has been observed that the addition of methanol has contributed to the improved combustion and resulted in lower fuel consumption to develop unit power. As the percentage of methanol increased, a significant reduction in BSFC has been observed at all ignition timings.
- Methanol blends in the gasoline reduced CO emissions at all engine operations owing to the fact that the presence of molecular oxygen in the fuel is believed to have helped to improve the combustion and reduced CO and HC emissions.
- NO_x emissions on the other hand are found to be reduced with all methanol blends. This is attributed to the lower heating value and higher latent heat of vapourisation of the methanol blends resulted in lower combustion temperatures and produced lower NO_x emissions compared with that of pure gasoline.

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