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ARTICLE *in* ENERGY & FUELS · JANUARY 2004

Impact Factor: 2.79 · DOI: 10.1021/ef030103d

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Effect of Methanol Addition on the Performance of Spark Ignition Engines

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Received April 24, 2003

This study is an experimental investigation into the effect of methanol addition to gasoline on the performance of spark ignition engines. The performance tests were carried out, at wide open throttle and variable speed conditions, over the range of 1000 to 2500 rpm, using various blends of methanol−gasoline fuel. It was found that 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 cosumption, occurs when a mixture of 15 volume percent methanol and 85% gasoline blend is used. The addition of methanol to gasoline increases the octane number, thus engines fueled with methanol−gasoline blend can operate at higher compression ratios.

1. Introduction

Gasoline needs no introduction. It is the fuel of the majority of spark ignition-engines with the transport sector being the most oil-dependent on all major energy-consumption sectors in the present economy. For nearly a century, automotive power plant design has evolved with the prime objective of high specific power output, good durability, low cost, and low fuel consumption. This, however, has changed due to many factors. Some of these factors may be summarized as follows:

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

These factors, in addition to many others, have initiated the incentive for the search for alternative sources of energy, which are cleaner and more environmentally friendly. These alternatives may be either complete replacement for the present fuels or additives that can be added to the present fuels to improve its properties.

Reviewing the literature[1−5] regarding the diagnostics of the problems with gasoline and the proposed solutions available, it was found that the following basic problems with gasoline exist:

1. Gasoline is a mixture of various hydrocarbons that have different physical and chemical properties. Therefore, it is difficult to control or produce homogeneous mixtures within standard specifications.
2. To meet the octane demand of unleaded gasoline, more of the dense aromatics have to be produced in catalytic reformers which lead to increased density of unleaded gasoline which causes problems with mixture formation, combustion, and emissions.
3. The suggested solutions to gasoline combustion problems such as the use of multi spark plugs or multi valve or supercharged or turbocharged engines adds more complications to the design, increases cost, increases frictional losses, increases the number of components to be maintained, adds more to the cost of gasoline-powered engines, and raises serious doubts about the net gains profited in terms of financial and technical areas.

The proposed solutions to circumvent the problem could be categorized into two basic approaches:

1. Change/Modify the attitude toward the present fuel, i.e., gasoline.
2. Search for new alternatives.

In this study, the first approach was selected with the aim of improving the combustion characteristics of gasoline, which will be reflected in improving the engine

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10.1021/ef030103d CCC: $27.50
Published on Web 01/13/2004

performance. This is done by mixing gasoline with a certain amount of a known substance that helps in boosting its combustion. Methanol was chosen in this study as an additive to improve gasoline combustion qualities. An investigation is to be carried out to find the best methanol–gasoline blend, which will give the best or optimum engine performance.

Methanol, also known as methyl alcohol, has been used as a fuel for automotive engines in many countries, especially in Indianapolis (USA).[6] Its excellent combustion properties have made it the strongest choice of the automotive industry.[7] Its power and safety benefits have prompted its use in the racing industry; its low emissions characteristics have generated considerable interest, from the Environmental Protection Agency (EPA), and from state and local air quality agencies in many countries. The other most important characteristic of methanol is that it is undoubtedly the cheapest liquid alternative fuel per calorific unit, which can be produced from the widely available fossil raw materials.[7] Current research[8] is investigating the possibility of producing it from biomass and municipal solid waste as potential feedstock. Many other production processes are also under development but have not yet become available commercially . This essentially means that many countries can solve their energy imbalance problems due to petroleum shortage by using methanol as a source of energy.

One of the possible ways of using methanol is to mix it in certain proportions with gasoline to improve its qualities. This has been the subject of extensive research for many years. Heinrich et al.[7] have investigated the suitability of methanol as a fuel, especially for heavy-duty commercial vehicles using both spark and high compression ratio as means for initiating combustion. They came to a basic conclusion that it is suitable for both the systems and for certain heavy-duty applications. Prakash,[9] Barrington,[10] Colledge,[11] and many others have investigated the use of methanol as a fuel for light- and heavy-duty vehicles, from various points of views. Hamdan and Jubran[12] investigated the effect of ethanol percentage in gasoline and diesel on their respective engine performance. They found that the best performance was achieved with 5% ethanol addition, and that the thermal efficiency was improved, in the range of 4 to 21%, under low- and high-speed conditions, respectively. They also found that no effect of ethanol on the engine's noise levels compared with their respective pure fuels. Alasfour[13] studied the effect of elevated temperatures on the performance of spark ignition engine and NO_x emissions for 15% methanol–gasoline fuel blend. He observed that by using 15% methanol–gasoline blend, the engine performance curves (brake power, mechanical efficiency, and thermal efficiency) showed reduction, for each fuel, when inlet air is preheated. The experimental results show that a 10% reduction in maximum NO_x emission level can be achieved when 15% methanol–gasoline blend was used compared to pure gasoline. Huanran and Rui[14] found that by mixing 5–30 vol % of pure methanol with commercial gasoline, and treating the mixture in an electrical field at 6–35 V and 0.1–30 MHz for 10–50 min, the mixed fuel is superior in combustion efficiency and low noxious emissions. Koenig et al.[15] studied the technical and economical aspects of methanol as an automotive fuel. From their results conducted on a single-cylinder engine and using methanol–gasoline blend as alternative fuel for motor vehicles, they found that such a mixture improved energy utilization, increased engine output, and improved knock resistance. They concluded that the utilization of antiknock effect of methanol could lead to competitive gasoline–methanol blend vehicle operation at the present cost of gasoline and methanol. Also, vehicle operation on pure methanol would offer economical advantages over gasoline operation if methanol is derived from coal.

Kelkar et al.[16] made a comparative study of methanol, ethanol, 2-propanol, and butanol as motor fuels in both pure form and blended with gasoline. They found that 10:90 (%) alcohol–gasoline blend can be used to fuel the engine without modifications. Some modifications such as carburetor adjustment and ignition timing are necessary in order to fuel the engine with 50:50 (%) alcohol-gasoline blend. Eveleth[17] studied the performance of various fuels such as gasohol, liquid propane, synthetic oil, alcohol (199.9 proof ethanol), natural gas and a combination of 50:50 (%) ethanol–methanol blend, in a variety of piston aircraft engines. The superiority of alcohol for aviation fuel was demonstrated in his research work.

2. Experimental Apparatus and Setup

Gasoline with octane number = 89 was selected, and mixed with different percentages of methanol. The following volume percentages of methanol were added 3%, 6%, 9%, 12%, and 15%. The methanol percentages for this study were selected such that methanol percentages were varied till octane number equal to 100 (at 15% methanol) was achieved.

The tests were carried out at the University of Jordan's laboratory, to study the effect of these fuel blends on the engine's performance. This was done using the TD43 engine. This is a 4-stroke, single-cylinder, variable compression ratio engine having a displacement volume of 582 cm^3. An electrical dynamometer is directly coupled to the engine for starting and

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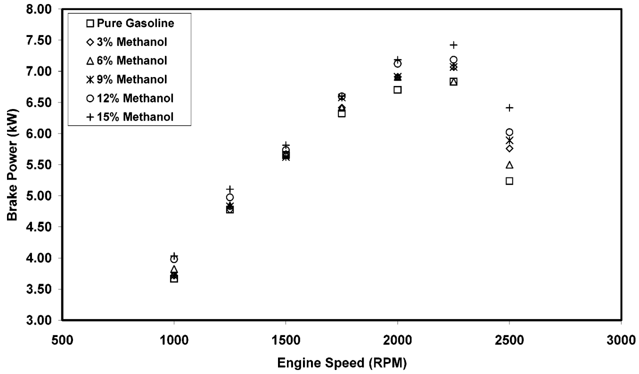

Figure 1. Brake power versus engine speed using various methanol–gasoline blends.

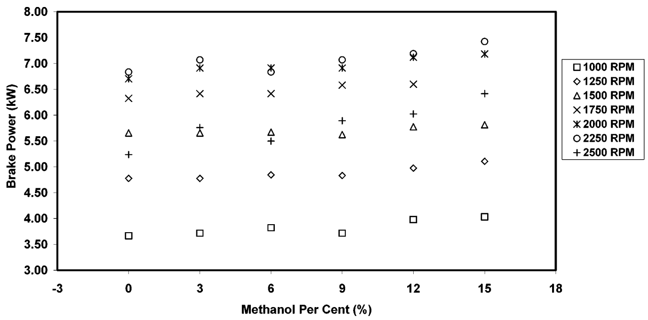

Figure 2. Brake power versus methanol percent at different speeds.

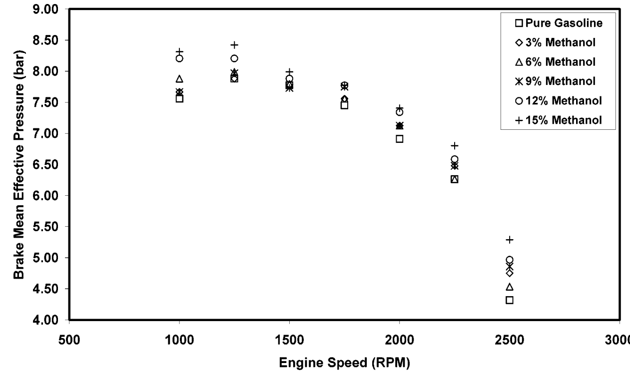

Figure 3. Brake mean effective pressure versus engine speed using various methanol–gasoline blends.

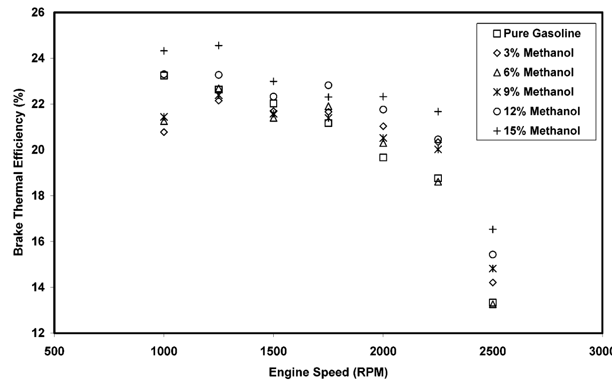

Figure 4. Brake thermal efficiency versus engine speed using various methanol–gasoline blends.

for friction power tests. The experimental data of brake torque, brake power, and air and fuel flow rate were directly obtained from the engine control panel, while the ambient conditions were obtained through the barometer.

With the engine compression ratio fixed at 8, with the fuel flow control knob opened at its optimum level as recommended by the manufacturer, and at engine speed of 1500 rpm, the ignition angle was varied to find the best torque angle. This angle was found to be 15 degree before top dead center, and was fixed for the rest of the experiments. All measurements were performed under wide-open throttle and variable speed conditions, over the range of 1000 to 2500 rev/min in steps of 250 rev/min.

The experimental tests started with pure gasoline, to set a database performance level on the basis of which the comparison will be carried out. Then for each type of gasoline–methanol blend, the performance tests under the same conditions were performed.

3. Results and Discussion

Engine performance characteristics are a convenient graphical presentation of an engine performance, operating at certain conditions. In the present paper, they are constructed from the data obtained during actual testing, through a series of runs at wide-open throttle, variable speed, and constant load.

The effect of methanol addition to gasoline on the power output from the engine is shown in Figures 1 and 2. The increase in power output was as high as 16% when a 15% methanol fuel blend was used, which gave the maximum increase in the power output for the speed range studied. This indicates that methanol has a significant effect on the power output from the engine. Methanol will ignite much less readily than gasoline. The lower volatility of methanol produces approximately one-third the volume of vapor per unit time for the same volume source as does gasoline.[6] It has a relatively high anti-knock or octane rating. Thus it has the ability to raise considerably the octane rating of gasoline. Knock in the S. I. engine combustion chamber causes a very high rate of energy release, excessive temperature, and pressure inside the cylinder and adversely affects its power output. In addition, methanol's greater heat of vaporization cools the air in the engine to a larger extent, thus increasing the density of the air and allowing more air in. This results in leaner fuel mixture, possibly lowering emissions of CO due to more complete combustion. Therefore, as the percentage of methanol in gasoline is increased, the probability of knock decreases and more complete combustion of the blend occurs. This improves the power output of the engine per unit fuel consumed.

The effect of methanol percentages on the brake means effective pressure (BMEP) as shown in Figure 3. It is clear that the best BMEP occurs when methanol percentage is 15%. This increase is due mainly to the greater volumetric efficiency that results from the higher latent heat of vaporization of methanol, which cools the air in the engine to a larger extent, thus increasing the density of the air and allowing more air in, resulting in a greater mass density of the fuel–air mixture.

The thermal efficiency of the engine increases with the addition of methanol as shown in Figure 4. As expected, the maximum increase in thermal efficiency occurs when methanol percentage is 15%, which also corresponds to the maximum power output as shown in Figure 1. This is in agreement with the results of Herz,[18] who found that the efficiency of the engine increases with the increase in methanol concentration.

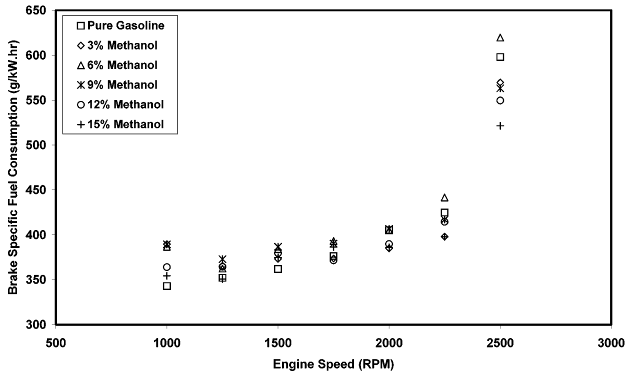

Figure 5. Brake specific fuel consumption versus engine speed using various methanol−gasoline blends.

The effect of methanol addition on the brake specific fuel consumption (BSFC) is shown in Figure 5. Brake specific fuel consumption (BSFC) is inversely proportional to thermal efficiency and calorific value of the blend. The calorific value of the blend decreases as the percentage of methanol increases. At low engine speed (1000 to 1500 rpm), the effect of the decrease in BSFC seems to be the dominant factor. This may explain that the smallest BSFC at these speeds is for pure gasoline. On the other hand, at engine speeds higher that 1500 rpm, the effect of increase in thermal efficiency of the blend seems to be the dominant factor, resulting in reducing BSFC with increasing the methanol percentages. The maximum decrease in BSFC occurs at 2500 rpm. It is clear from Figure 5 that BSFC increases sharply at high speeds. This is because at high speeds, the friction power is increasing at a rapid rate, resulting in a slower increase in brake power than the fuel consumption, with consequent increase in BSFC. The optimum engine speed is 1250 rpm for all methanol percentages studied.

4. Conclusions

The main conclusions deduced from this investigation are as follows:

1. Methanol has a significant effect on the performance of the gasoline engine.

2. The best engine performance, maximum power output, and minimum brake specific fuel consumption, occurs when a 15 vol % methanol/85 vol % gasoline blend is used.

3. The best operating conditions, with regard to brake specific fuel consumption, is operating the engine at low and moderate speeds.

4. The addition of methanol to gasoline increases the octane number. Hence, it enables the gasoline engine to operate at higher compression ratios.

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