# FUEL CONSUMPTION OF A SPARK IGNITION ENGINE BLENDED WITH MTBE

**Abdulghani A. Al-Farayedhi**[1]

*1: Associate Professor, Mechanical Engineering Department, KFUPM*
*E-mail: aghani@kfupm.edu.sa*

## ABSTRACT

*Gasoline engines are widely used in automotive applications and power generation. In these engines, the combustion of converting the fuel energy into mechanical work through combustion takes place rapidly in cycles. An important parameter used as an indicator to the efficiency of engines is the brake specific fuel consumption (bsfc). The equivalence ratio has an appreciable effect on the engine performance. This paper studies experimentally the effects of using an oxygenate namely methyl teriary butyl eyher (MTBE) on bsfc of a typical spark ignition engine. MTBE, which was blended with unleaded fuel in three ratios, was investigated. The engine sfc was measured at a variety of engine operating conditions using an engine dynamometer set-up. This paper presents the comparison of bsfc between the fuel blended with MTBE and the unleaded fuel. The results are presented in terms of equivalence ratio and their effects are discussed in this paper.*

**Keywords:** *gasoline engine, MTBE, specific fuel consumption, unleaded fuel*

## الملخص

يستخدم وقود البنزين بشكل واسع فى مكائن السيارات وانتاج الطاقة. تتحول طاقة الوقود الى طاقة ميكانيكية عن طريق الاحتراق والذى يحدث بسرعة فائقة وعلى شكل دورات. يعتبر المعدل المكبحي النوعي لاستهلاك الوقود عامل مهم لمعرفة كفاءة مكائن الاحتراق. كما أن نسبة الوقود التكافؤية لها تأثير مباشر على اداء المكائن. تقدم هذه الورقة دراسة معملية عن تأثير المادة المؤكسدة المسماة (ام.تي.بي.إي) على المعدل المكبحي النوعي لاستهلاك الوقود لمكائن البنزين. اجريت الدراسة باستخدام وقود خليط مكون من بنزين خالي من الرصاص والمادة المؤكسدة بثلاث نسب مختلفة. ولقد تم قياس استهلاك الوقود لظروف تشغيلية متعددة لاداء الماكينة وذلك باستخدام جهاز المكائن الديناموميتري. تقدم هذه الورقة دراسة مقارنة لاستهلاك الوقود الخالي من الرصاص مع الوقود المخلوط بالمادة المؤكسدة. كما تعرض مناقشة نتائج الدراسة وتأثيرها بالنسبة الى نسبة الوقود التكافؤية.

## 1. INTRODUCTION

Gasoline for use in spark ignition engine consists of a complex mixture of several hydrocarbons. Gasolines are blended from various refinery streams so that the finished product will provide satisfactory specific fuel consumption under a variety of operating conditions.

The effect of gasoline octane requirement on the engine performance and the environment has attracted the interests of many scientists. The effect of MTBE in gasoline on exhaust emission was studied [Al-Farayedhi et al., 2000]. The MTBE has different chemical and physical properties when compared to gasoline. These differences are expected to influence the combustion process and hence the specific fuel consumption of gasoline-MTBE blends. This paper deals with the experimental study that aims to examine the effects of using MTBE on the specific fuel consumption of a typical automotive engine. This paper also offers a comparison between the MTBE oxygenated and unleaded fuel in terms of the specific fuel consumption.

## 2. FUELS USED FOR THE TEST

The aim of the study is to investigate the effects of MTBE blends on the brake specific fuel consumption of a typical spark ignition engine. A base fuel was prepared by mixing 20% of naphtha with 80% of reformate on volumetric basis. The rating of research octane number (RON) was carried out in the Heat Engines Laboratory of the Mechanical Engineering Department at KFUPM and was found to be 84.7. RON is a measure of fuel quality and performance and is affected by the type of hydrocarbon, additives such as tetramethyl lead and tetraethyl lead and sulfur content in the gasoline. A leaded fuel was prepared by adding tetra ethyl lead (TEL) to the base fuel. The addition of TEL brings the lead concentration in the fuel to 0.4 g pb/Liter with a RON of 92.

Oxygenates are currently used in gasoline as an alternative to the phased-out lead compounds. One of the most commonly used oxygenates is MTBE (methyl tertiary butyl ether, $C_4H_9$-O-$CH_3$). MTBE is manufactured from isobutane ($(CH_3)_3CH$). This oxygenate has different chemical and physical properties when compared to gasoline. These differences are expected to influence the performance and combustion products of gasoline-oxygenate blends. Instead of TEL, the MTBE was blended with the base fuel in three ratios: 10, 15, and 20 % by volume in order to increase the unleaded fuel RON. The purity of the MTBE was 98.71 wt. %. These MTBE/base blends were designated MTBE10 (10 vol.% MTBE + 90 vol.% base), MTBE15, and MTBE20 respectively. The relevant physical and chemical properties of the test fuels were determined. Tables 1 and 2 list the properties for the MTBE and the test fuels respectively. Some of the listed properties were not measured but rather obtained from literature. The measurements of specific gravity, Reid vapor pressure, and distillation characteristics were conducted at King Fahd University of Petroleum and Minerals.

Top

Table 1 Properties of the oxygenate tested in this study

| **Property** | MTBE |
|---|---|
| Weight percent oxygen | 18 |
| Reid vapor pressure (kPa) | 61.2 |
| Boiling temperature, °C | 53.3 |
| Specific gravity @ 15.56 °C | 0.7461 |
| Research octane number | 116 * |
| Lower heating value (MJ/kg) | 35.2 ** |
| Latent heat of vaporization (kJ/kg) | 340 ** |
| Stoichiometric A/F ratio | 11.76 |

* Obtained from SAE handbook [1992] for pure MTBE

** Obtained from Heywood [1988]

Table 2 Properties of the test fuels

| Fuel Property | Base | Leaded | MTBE10 | MTBE15 | MTBE20 |
|---|---|---|---|---|---|
| Specific gravity @ 15.56°C | 0.7697 | 0.772 | 0.7638 | 0.7633 | 0.7628 |
| Rvp, kPa | 35.0 | 33.6 | 41.0 | 41.6 | 42.4 |
| Research octane number | 84.7 | 92 | 87.9 | 89.8 | 91.7 |
| Heat of vaporization, kJ/kg * | 350 | 350 | 349 | 349 | 348 |
| Weight percent oxygen * | 0 | 0 | 1.77 | 2.66 | 3.55 |
| Heating value, MJ/kg * | 44 | 44 | 43.144 | 42.715 | 42.283 |
| Stoichiometric A/F * | 14.6 | 14.6 | 14.33 | 14.19 | 14.05 |
| Hydrocarbon types, vol. % ** | | | | | |
| N-Paraffins | 8.78 | 8.78 | 7.91 | 7.47 | 7.03 |
| Iso-Paraffins | 43.60 | 43.60 | 39.24 | 37.06 | 34.88 |
| Naphthenes | 3.83 | 3.83 | 3.45 | 3.26 | 3.07 |
| Aromatics | 42.54 | 42.54 | 38.28 | 36.16 | 34.03 |

* Typical or calculated values and, if applicable, adjusted for the presence of added oxygenate

** Analysis was conducted on reformate and naphtha then calculated and, if applicable, adjusted for the presence of oxygenates

Top

## 3. EXPERIMENTAL SET-UP

This current experimental study is aimed to help in understanding the effect of the MTBE on the fuel consumption of a typical automotive engine. The study offers a comparison between the oxygenated and leaded fuels in terms of the specific fuel consumption.

The experiments were conducted using a six-cylinder engine. This engine is manufactured by Mercedes-Benz and has a swept volume of 2960 $cm^3$. It has a bore of 88.5 mm, a stroke of 80.2 mm, a compression ratio of 9.2, and a maximum power of 132 kW at 5700 rpm. The engine is equipped with the KE-Jetronic continuous fuel injection system. The engine has an electronic ignition system with an electronic spark timing adjustment. The temperatures of cooling water and lubrication oil are controlled by two fitted heat exchangers. The engine is coupled to an eddy-current dynamometer. This eddy-current dynamometer is electronically controlled and water-cooled. It has a maximum power of 257 kW, a maximum torque of 1400 Nm, and a maximum speed of 8000 rpm. For more information on the test equipment used in this study, refer to Al-Farayedhi et al. [2000].

## 4. TEST CONDITIONS

All the tests were carried out with the spark timing being manually adjusted to the maximum brake torque (MBT) timing. The test engine is equipped with an electronic ignition system with an electronic timing adjustment. This system adjusts the spark timing to preset values depending on the engine speed and the intake vacuum that represents the engine load. The system has no means for mechanical adjustment of spark timing. In order to adjust the timing, the intake vacuum hose that carries the load signal to the ignition system controller was disconnected from the intake manifold and connected instead with a manual vacuum pump. In other words, the load signal was controlled so that the ignition system controller adjusts the spark timing as desired.

This system contained an electrohydraulic pressure actuator capable of controlling the air/fuel ratio. To make use of this actuator and to avoid the tedious mechanical adjustment, a special device was constructed to electrically control the air/fuel ratio by supplying a small controlled direct current to the actuator through a dc generator. The mechanical adjustment was used in cases where electrical control could not achieve the desired setting. The temperatures of the cooling water and the lubrication oil were controlled by two fitted heat exchangers. In all the tests, the cooling water temperature was kept at 80 ± 5 $^oC$. The temperature of the lubrication oil was kept at 80 ± 2 $^oC$. The test room temperature was kept at 25 ± 2 $^oC$. The recorded atmospheric pressure in the test room ranged from 99.4 kPa to 100.9 kPa.

Top

## 5. RESULTS AND DISCUSSION

The specific fuel consumption of the test engine operating with the test fuels at a variety of conditions that span the practical operating range of normal automotive engines is measured. The specific fuel consumption was measured in a wide-open throttle variable-speed test. The MBT timing values and the exhaust gas temperatures were closely examined in order to help in understanding the results and explaining the variations between the fuels.

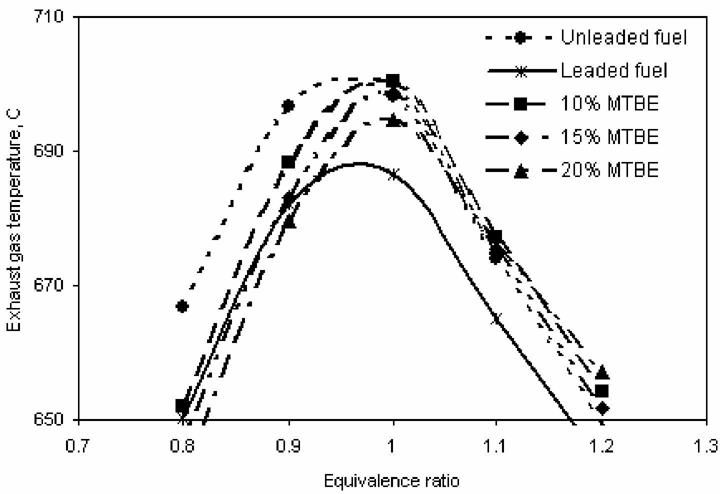


Fig. 1: The effect of equivalence ratio on the exhaust gas temperature

The effect of equivalence ratio on the exhaust gas temperature was measured at a constant speed (2000 rpm), constant load (680 kPa), and MBT timing. The exhaust gas temperatures, shown in Fig. 1, peak at about stoichiometric ($\Phi = 1.0$) and sharply drop with lean and rich mixtures. This indicates that the maximum heat loss through the exhaust process occurs in the case of stoichiometric mixtures. It indicates also that the prevailing gas temperature at the end of the expansion process is higher in the case of stoichiometric than in lean or rich mixtures. In general, the exhaust gas temperatures for the MTBE blends were comparable to those of the unleaded fuel in the case of rich mixtures but noticeably lower in the case of lean mixtures. The leaded fuel exhibited a consistent decrease in exhaust temperature with respect to the base fuel over the entire test range. The decreased exhaust temperature is a result of lower combustion temperature and/or improved thermal efficiency. The heating value of a fuel, usually measured in MJ/kg, is a measure of its energy content. The addition of MTBE to unleaded fuel can have more pronounced effects on fuel economy due to their lower heating values as given in Table 2. Two factors should be considered when assessing the effect of MTBE on fuel economy [Dorn and Mourao, 1984]. The first factor is the lower energy content of MTBE blend fuels relative to unleaded fuel results in poorer fuel economy. A second factor that also affects fuel economy is the change in the stoichiometric air/fuel ratio of the intake charge. The addition of MTBE to the unleaded fuel causes a shift to leaner combustion and can either increase or decrease fuel economy depending on how the carburetor is tuned.

The effect of equivalence ratio on the engine brake specific fuel consumption was measured and the results are shown in Fig. 2. As the equivalence ratio increases the specific fuel consumption increases. Leaded fuel gave the lowest brake specific fuel consumption under the given operating conditions as compared with MTBE blends and the unleaded fuel. This result can be attributed to the effect of higher heating value of leaded fuel. For the MTBE blends, the change in bsfc is insignificant for different MTBE ratios for lean fuel mixtures (that is, equivalence ratio from 0.8 to 1). However, for rich mixtures (equivalence ratio from 1.0 to 1.3), 20% MTBE blend gave the lowest brake specific fuel consumption.

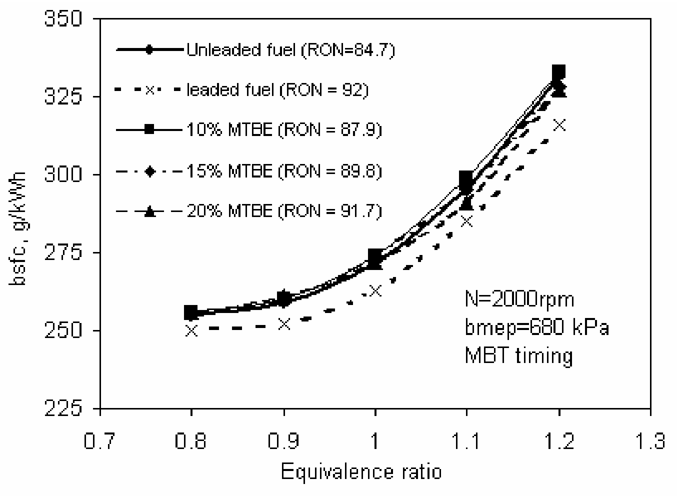


Fig. 2: The effect of equivalence ratio on the engine bsfc

The effect of engine speed on the engine brake specific fuel consumption is shown in Fig. 3 for leaded fuel and 20% MTBE fuel blend. The range of speed investigated was 1000 to 3500 rpm. Leaded fuel gave the lower brake specific fuel consumption at 1000 rpm but as the speed increases 20% MTBE fuel blend gave the lower brake specific fuel consumption.

The brake specific fuel consumption for different MTBE blends are compared with the unleaded fuel (RON = 84.7) for the same operating conditions. The results are shown as percentage difference of brake specific fuel consumption over the unleaded fuel in Fig. 4. For lean mixtures, the MTBE blends gave higher brake specific fuel consumption of about 0.6%. However, for rich mixtures, the MTBE blends gave brake specific fuel consumption of 2% less than the leaded fuel. This may be due to the improvement in combustion process due to presence of 2 to 4 wt % oxygen in MTBE blends in the rich mixtures. The figure also shows that for rich mixtures as the percentage of MTBE blended with the base fuel increases the reduction in bsfc also increases.

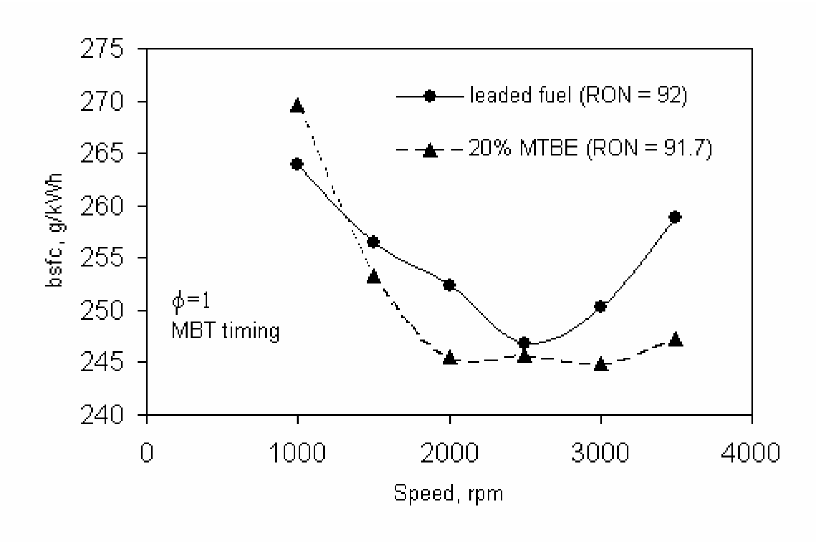


Fig. 3: The effect of engine speed on the engine bsfc

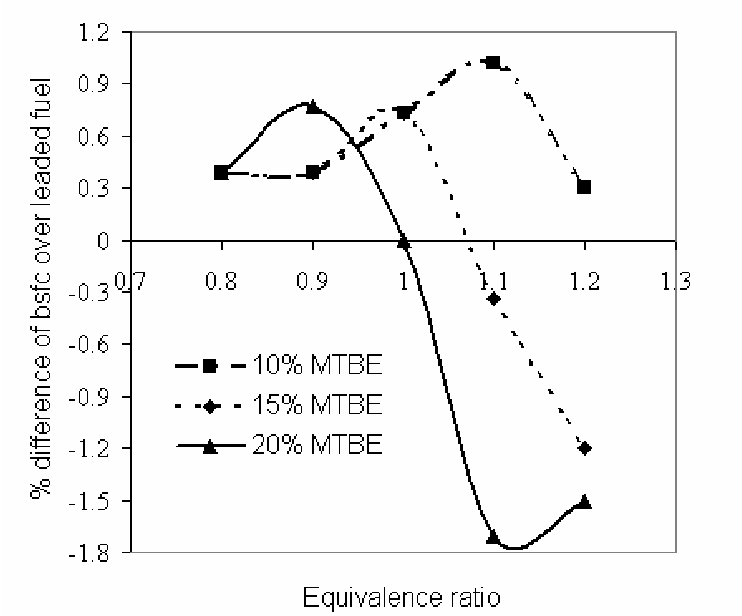


Fig. 4: The percentage difference of bsfc over the leaded fuel

Top

## 6. CONCLUSIONS

The effects of MTBE on brake specific fuel consumption of a spark ignition engine were investigated experimentally. It is found that as the equivalence ratio increases the brake specific fuel consumption increases. Leaded fuel gave the lowest brake specific fuel consumption under the given operating conditions. However, for rich mixtures the lowest brake specific fuel consumption was achieved by the 20% MTBE blend. Generally, for lean mixtures, the MTBE blends gave higher brake specific fuel consumption and for rich mixtures the MTBE blends gave lower brake specific fuel consumption.

## ACKNOWLEDGEMENTS

The author is grateful for the financial support and facilities provided by the King Fahd University of Petroleum and Minerals for this research.

## REFERENCES

1. Al-Farayedhi, A. A., Al-Dawood, A. M. and Gandhidasan, P., 2000, "Effects of blending MTBE with unleaded gasoline on exhaust emissions of SI engine," *Trans. of ASME Journal of Energy Resources Technology*, **122**, pp. 239-247.
2. Dorn, B. and Mourao, A. M., 1984, "The properties and performance of modern automotive fuels," SAE paper 841210.
3. Heywood, J. B., 1988, Internal Combustion Engine Fundamentals, McGraw-Hill, New York.
4. SAE Handbook, 1992, Alternative automotive fuels, SAE J1297 JUN90, Volume 3, Society of Automotive Engineers.

Top