A Review on the Use of the Blend of Alcohol and Ether in the Spark Ignition Engine

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ABSTRACT: Energy security and global warming concern are the two main driving forces for the global alcohol development that also has the effort to animate the agro-industry. Generally, alcohol and ether fuels are produced from several sources and can be produced locally. Nearly all alcohol fuels have comparable characteristics of combustion and ignition to existing known mineral fuels. In order to increase the amount of octane and oxygen content of gasoline, ether fuels (MTBE and DME) are primarily used as additives at low blending ratios. The addition of alcohol and ether fuels to gasoline lead to a complete combustion due to the higher oxygen content, thereby leads to increased combustion efficiency and decreased engine emissions. The goal of this paper is to systematically investigate the use of alcohols and ethers such as butanol, methanol, ethanol, fusel oil, MTBE, and DME as SI engine fuels. The performance effects (brake torque, and efficiency emissions (CO, CO2, NOx and HC). The increase in engine performance could be attained with an increased compression ratio along with the use of alcohol fuels which have a higher-octane value. Furthermore, alcohol and ether burn very cleanly than regular gasoline and produce lesser carbon monoxide (CO) and nitrogen oxide (NOx) (NOx). On the other hand, the energy content of alcohol and ether fuels is roughly 30 percent lower than that of gasoline, thus raising the real fuel consumption (SFC) when alcohol and ether are used as fuel at the same time. Finally, this paper also discusses the impacts of alcohol on engine vibration, engine noise, and potential to be used as a gasoline octane enhancer. Alcohol can be used as a pure fuel in spark ignition engine, but it requires some modifications to the engine.

KEYWORDS: Alcohols fuel, Ether, Spark ignition engine, Engine emissions, Combustion characteristics.

INTRODUCTION

Energy security is becoming increasingly critical and is one of the governmental concerns worldwide. More than half of the world's primary energy consumption is actually accounted for by the combustion of fossil fuels such as gasoline and diesel. With rising fossil oil prices and global warming continuing to be a dominant environmental problem, the potential use of renewable fuels appears to be unavoidable. Fossil fuels are generally considered to be energy sources that are non-renewable [1]. Alcohols as fuels in internal combustion engines have a long history of around 100 years (ICE). Alcohol-based fuels may have been considered as one of the renewable options, with the ability to be used by effective biomass conversion in a nearly CO2-neutral manner [2]. The use of alcohol as a transportation fuel, particularly in light cars, is not new, but has recently begun to attract significant global attention. Fuels in ICE are alcohols such as ethanol, butanol, methanol, and fusel oil and ethers (methyl tertiary butyl ether (MTBE) and dimethyl ether (DME)). To date, first-generation alcohols have primarily been focused on gasoline-ethanol blends for Spark Ignition (SI) applications, where current fuel quality requirements usually allow between 5-10 percent ethanol inclusions within an established gasoline pool [3].

As an ether fuel, dimethyl ether (DME) does not have a long history as a combustion fuel or gasoline additive in the SI engine, but the combination of DME with gasoline in the SI engine appears to be a potential solution for improving combustion and improving engine thermal efficiency under normal operating conditions [4]. It is possible to generate dimethyl ether CH3OCH3 (DME) from feedstock variations such as crude oil, natural gas, coal, residual oil, biomass, and waste products. DME has many strong properties and is considered to be one of the best alternative fuels in the future for IC engines. In addition, a variety of DME investigations have been performed to evaluate its suitability for use as a fuel additive in an ethanol engine with spark ignition. Overall, as it has low combustion noise, high thermal efficiency, soot-free combustion, and low NOx levels, dimethyl ether has been found to be a promising alternate additive fuel for spark ignition engines. DME addition can be considered as a potential solution to improve the overall performance of ethanol engines with spark ignition.

In addition, DME enhances the economic and emission efficiency of the engine when it is used in the SI engine as an additive to the gasoline-ethanol blend. Methyl tert-butyl ether (MTBE) based ether and oxygenated fuel has been used in gasoline in Germany since 1985 to increase the octane value and increased engine emissions. A volatile organic compound generated by the chemical reaction of isobutylene and methanol is MTBE (methyl tertiary-butyl ether). MTBE (C5H12O) is produced in very large quantities (over 200,000 barrels/day in the US in 1999) and is almost entirely used in petrol engines as a fuel additive. Because of its low price, ease of processing, and favorable transfer and blending characteristics, MTBE is the most widely used ether fuel. To minimize toxic emissions, it is also linked to gasoline. Since 1979, methyl tertiary-butyl ether (MTBE) has been attached to gasoline in the United States, primarily as an octane booster to replace lead. The use of MTBE has increased significantly since that date and reached about 408,000-453,592.37 Metric Tons in 1997. While MTBE was used in the US as a gasoline additive in 1979, it was formerly used to substitute lead as an anti-knock agent. Sezer et al. have shown that mixing gasoline with MTBE has improved the spark ignition engine's efficiency and CO emissions [5]. The highest increase in BMEP values is obtained by adding 10 percent of MTBE to gasoline. The improved brake thermal efficiency (BTE) of MTBE10 contributed to a blending ratio of up to 15 percent.

Properties of alcohol and ether fuels. The chemical and physical properties of the combustion fuel relate to the nature of the combustion fuel in the engine. Moreover, they are correlated with engine performance, combustion efficiency, and emission characteristics. In Table 1, the key properties of alcohol and ether fuels are shown. The chemical formula of C5H12O is able to express fusel oil and MTBE (methyl tertiary-butyl ether). Ethanol with dimethyl ether is also isometric. The same chemical formula is used (DME) and both DME and ethanol (C2H5OH). The oxygen atoms in their molecular compounds, especially in methanol or ethanol (alcohol), which contribute to reducing CO and HC emissions, are one of the most important properties of alcohol and ether fuels. In addition, the number of octanes, other main characteristics of alcohol fuels used in spark ignition engines, is related to the volatility of the fuels. Alcohol fuels have latent evaporation heat (LHOV) that is 3-5 times higher than gasoline.

The LHOV affects the cold start potential of the SI engine, which contributes to an improvement in volumetric performance and decreases the temperature of the intake manifold. For example, methanol's latent heat of vaporization (LHOV) is around 2.5 times higher than gasoline. On the other hand, to achieve equivalent energy production, the heating value of alcohol and ether fuels is 20-40 percent lower than unleaded gasoline and requires 1.5-1.8 times more alcohol fuels. At the same time, low alcohol and ether fuel heating values result in lower exhaust temperatures and lower engine emissions. A significant property of engine fuels is vapor pressure. In addition, the vapor pressure can influence the engine's proper cold start. In addition, vapor pressure is a crucial element in meeting the criteria for evaporative emissions. Vapor pressure is defined as the vapor pressure of the Reid (RVP). The Reid vapor pressure (RVP) for alcohol fuels is typically 17-55 kPa, lower than 53-60 kPa for gasoline.

Table 1: Chemical and physical properties of primary alcohols, ethers and gasoline.

	Gasoline	Butanol	Methanol	Ethanol	MTBE	DME	Fusel oil
Chemical Formula	$C_{5-10}H_{12-22}$	$C_4H_{10}O$	CH_3OH	C_2H_5OH	$C_5H_{12}O$	CH_3OCH_3	$C_5H_{12}O$
CAS Number	86290-81-5	35296-72-1	67-56-1	64-17-5	1634-04-4	115-10-6	8013-75-0
Molecular Weight mass%	106.22	74.12 [91]	32.04	46.7	88.15	46.07	76.42
Carbon mass%	87.5	64.91	37.5	52.2	66.1	52.2	54.8
Hydrogen mass%	12.5	13.49	/	34.7	13.7	13	15
Oxygen[(a)] mass%	0	21.6	49.93	34.7	18.2	34.8	30.32
Density, (g/ml)	0.737	0.810	0.792	0.785	0.74	0.661[b]	0.847
Boiling temperature, °C	27–225	117.25	78	78.25 [92]	52.2	−25.1 [55]	53.4–54.4
Reid vapor pressure, Kpa	53–60	18.6 [93]	32.4	17	54.47	/	/
Research octane no.	90–100	98	108.7	108.6–110	118 [94]	/	106.85
Motor octane no.	82–92	78	86.6	92	102	/	103.72
LHOV kJ/kg	349 [95]	707.9	920	923	320 [96]	/	/
LHV MJ kg^{-1}	44.0	33.2	20.1	26.9	34.9	28.8	29.536
Freezing point, °C	−40	/	−97.5	−114	−108	/	−52
Viscosity mm^2/s	0.5–0.6	/	0.596	1.2–1.5	0.35	/	0.61
Flash point, °C	−45 to −13	/	11	12–20	−25.5	/	/
Autoignition temperature, °C	257	385	423	425	435	253	41.6

Alcohols and ether as fuel blending for SI engine

The blending of gasoline-alcohol has attracted the attention of researchers in many countries including Brazil E5 - E85 (5–85 percent ethanol), Germany (3 percent, methanol), South-Africa (12 ~ 01 percent alcohol blend) and parts of the USA (10–01 percent ethanol). Alcohol can be blended with the gasoline by any proportion, and it can be operated in several internal combustion engines with little or no modification.

Methanol can be blended with gasoline in spark ignition engines in various amount. Gravalos et al. studied the emissions of higher-lower molecular mass alcohol-gasoline blends, whereby the alcohol component of the alcohol-gasoline blends consisted of propanol, ethanol, methanol and butanol [6]. It was found that CO and HC concentrations decreased under varying engine loads when running on alcohol gasoline blends, while NO emission produced by alcohol- gasoline blends was higher than that of gasoline. There are numerous fuel properties that are important for proper operation of gasoline in spark ignition engines. The addition of alcohol with gasoline affects certain key properties, particularly blend viscosity, stability, heating value and octane rating. Corrosiveness and material compatibility are also significant reasons for consideration. More importantly, any property that affects safety should be foremost in any fuel evaluation, which means that flammability and flashpoint should be considered. In summary, with increasing alcohol concentration in a blend, fuel properties change [7]. The heating value for all recorded fuels decreased with increasing alcohol concentration, while the kinematic viscosity and density of the blends increased. In addition, for all fuels, except butanol, the octane number increased. Such properties that have been altered play a major role in the performance and pollution of engines with spark ignition.

Impact of alcohol and ether fuel on SI engine output

The output features of spark ignition engines are directly related to be affected by the fuel type used. Engine strength, torque, SFC and brake thermal efficiency are these characteristics (BTE).

Effect on torque and power

Some studies have shown that engine torque has also increased fuel consumption significantly when alcohol fuels are used. This is because, relative to gasoline, alcohol has less energy per unit volume. Power and torque are highly dependent on the in-cylinder pressure of an engine. In 2014, Calam et al. experimented with a four-stroke, single-cylinder, SI Hydra engine operating at various engine speeds (1500, 2500, 3500 and 5000 rpm), 25 percent, 50 percent, 75 percent and 100 percent and different engine loads (F0, F10, F20 and F30). By the quantity of fusel oil in each test fuel, the torque increased at all loads and engine speeds. For the F30, the maximum engine torque was 2500 rpm. On a single cylinder, spray guided, 4-stroke DISI research engine at 1500 rpm engine speed, stoichiometric air-fuel ratio (AFR) and various engine loads between 3.5 and 8.5 bar IMEP, Chongming et al. used DMF, ethanol and gasoline, as well as using the optimum spark timings (MBT) [8]. They found that the combustion time for DMF was shorter than gasoline and ethanol at 8.5 bar IMEP motor load.4 and 1 degree crank angle, respectively. The highest in-cylinder peak pressure was produced by DMF, which was greater than that of ethanol. Due to elevated octane numbers, DMF and ethanol had greater ant-knocking than gasoline. The highest thermal efficiency was obtained at 8.5 bar IMEP when ethanol (38.5 percent) was used, while DMF and gasoline had 37 percent and respectively, 36 percent.

CONCLUSION

In meeting energy demand in the automotive sector, alcohol and ether play an increasingly important role. Data on different forms of alcohol (butanol, methanol, ethanol and fusel oil) and ether (MTBE and DME) have been summarized in this literature review in terms of their effect on spark ignition engines that could potentially substitute petroleum-based fuels or boost fuel characteristics. Before recommending the use of an alternative fuel for current technologies on a wide scale, several considerations have to be considered. The variables have been addressed by researchers and few of the significant variables are explained. Due to the high octane amount, alcohol fuels with high compression ratios should be used to improve the efficiency of SI engines. When using it as fuel, alcohol water content such as in fusel oil should be removed. Maximum alcohol and gasoline engine vibration values. In order to reduce the phase separation issue, co-solvents such as fusel oil should be used with methanol. Compared with the environmental compatibility of an alternative fuel.

REFERENCES

[1] N. Abas, A. Kalair, and N. Khan, “Review of fossil fuels and future energy technologies,” *Futures*, 2015, doi: 10.1016/j.futures.2015.03.003.

[2] I. M. Yusri *et al.*, “Alcohol based automotive fuels from first four alcohol family in compression and spark ignition engine: A review on engine performance and exhaust emissions,” *Renewable and Sustainable Energy Reviews*. 2017, doi: 10.1016/j.rser.2017.03.080.

[3] C. Arcoumanis, C. Bae, R. Crookes, and E. Kinoshita, “The potential of di-methyl ether (DME) as an alternative fuel for compression-ignition engines: A review,” *Fuel*. 2008, doi: 10.1016/j.fuel.2007.06.007.

[4] P. Geng, E. Cao, Q. Tan, and L. Wei, “Effects of alternative fuels on the combustion characteristics and emission products from diesel engines: A review,” *Renewable and Sustainable Energy Reviews*. 2017, doi: 10.1016/j.rser.2016.12.080.

[5] I. Sezer and A. Bilgin, “Effects of methyl tert-butyl ether addition to base gasoline on the performance and CO emissions of a spark ignition engine,” *Energy and Fuels*, 2008, doi: 10.1021/ef700592n.

[6] I. Gravalos, D. Moshou, T. Gialamas, P. Xyradakis, D. Kateris, and Z. Tsiropoulos, “Emissions characteristics of spark ignition engine operating on lower-higher molecular mass alcohol blended gasoline fuels,” *Renew. Energy*, 2013, doi: 10.1016/j.renene.2012.06.033.

[7] A. Calam, H. Solmaz, A. Uyumaz, S. Polat, E. Yilmaz, and Y. Içingür, “Investigation of usability of the fusel oil in a single cylinder spark ignition engine,” *J. Energy Inst.*, 2015, doi: 10.1016/j.joei.2014.09.005.

[8] C. Wang *et al.*, “Combustion characteristics and emissions of 2-methylfuran compared to 2,5-dimethylfuran, gasoline and ethanol in a DISI engine,” in *Fuel*, 2013, doi: 10.1016/j.fuel.2012.05.043.