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Overview of the oxygenated fuels in spark ignition engine: Environmental and performance

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ABSTRACT

Oxygenated fuels such as alcohols and ethers have the potential to provide reliable sources, and environmentally friendly fuel to world's increasing future energy demands. Oxygenated fuels have a promised future since are renewable and produced from several sources, also can be produced locally. The first objective of this paper is to systematically review of oxygenated fuels including alcohol and ether regarding the production, environmental impacts and potential using as octane booster of gasoline that used in spark ignition SI) engine. Another objective of this paper is to review the effects of oxygenated fuels on performances and emissions characteristics of spark ignition engine. Alcohol and ether burn very cleanly than regular gasoline and produce lesser carbon monoxide (CO) and nitrogen oxides (NO_x). Mainly the ether fuels (methyl tertiary butyl ether MTBE and Dimethyl Ether DME) are used as additives at low blending ratio to enhance the octane number and oxygen content of gasoline. Furthermore, alcohols and ethers have significant impacts on the environment, greenhouse gas and human health. In addition to this, application of oxygenated fuel on SI engines can decrease environmental pollution, strengthen agricultural economy and decrease gasoline fuel requirements. 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. Overall, oxygenated fuels have been found to be a very promising alternative fuel for SI engines, capable of providing high thermal efficiency, and lower NO_x levels.

1. Introduction

It is well recognized that transportation sector is almost entirely dependent on conventional fuels especially petroleum-based fuels such as gasoline and diesel fuel. Currently, combustion of gasoline and diesel account for more than half the world's primary energy use [1,2]. With the increasing cost of fossil oil and global warming continuing to be a dominant environmental concern, it seems that the use of alternative fuels in the future is inevitable [3]. TheEnergy Information Administration (EIA) reported the increase in the world energy consumption would be around 56% by 2040 compared with that of the year 2010 as shown in Fig. 1 Besides that, the increasing utilization of conventional fuels as major energy carriers and the resultant emissions have been valued as a serious environmental matter. Fig. 2 shows the increase of CO_2 emissions by 3.5 times from 1961 to 2010 that published by Carbon Dioxide Information Analysis Center (CDIAC).

Oxygenated fuels such as alcoholic and ether fuels which have significant oxygen content. Oxygenated can be naturally produced from conventional biomass resources which are environmentally friendly, are biodegradable and contribute to sustainability. Producing and utilizing oxygenated fuels in an internal combustion engine (ICE) an alternative to conventional fuels that can assist provide solutions to many environmental problems [6]. Actually, the utilizing of oxygenated fuels in internal combustion engine lead to reduce greenhouse gas (GHG) emissions compared to gasoline [7,8]. This could be explained by the low content of pollutants like sulfur in oxygenates, and to complete

Abbreviations: ICE, Internal combustion engines; RVP, Reid vapor pressure; LUC, Land-use change; GHS, Greenhouse gases; RON, Research octane number; MON, Moto octane number; TEL, Tetraethyl lead; BTE, brake thermal efficiency; BSFC, brake specific fuel consumption; VEL, various engine loads; VES, various engine speeds; DISI, Direct Injection Spark Ignition; DME, Dimethyl Ether; DMF, dimethylfuran; MTBE, methyl tertiary butyl ether; IMEP, indicated mean effect pressure; 3 C, three-cylinder; 4 C, four-cylinder; SC, single cylinder; 4 S, four stroke; CFR, cooperative fuels research; DST, different spark timing; CR, compression ratio; VCRC, variable compression ratio capabilities; LHOV, latent heat of evaporation; BTDC, before top dead center

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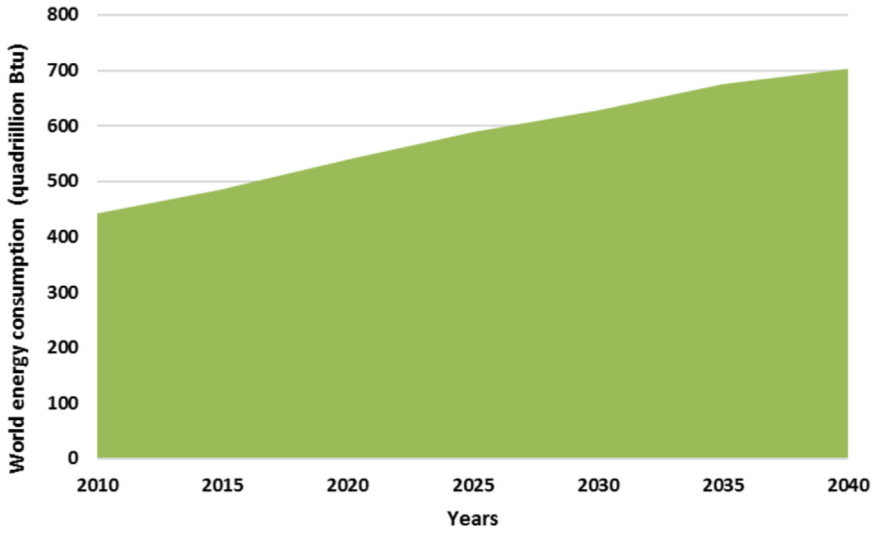

Fig. 1. The estimated amount of world energy consumption.
Source: EIA (2015) [4]

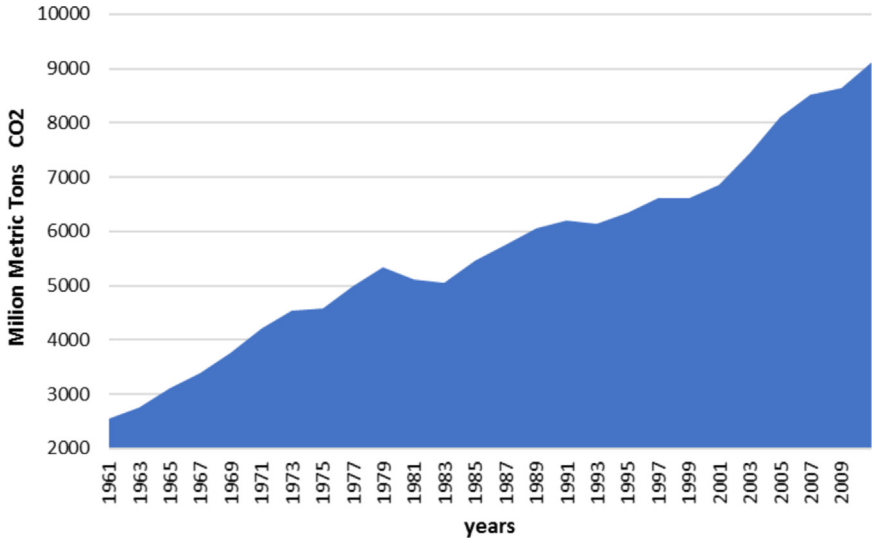

Fig. 2. The amount of CO_2 emission emitted.
Source: Marland, Boden et al., 2007 [5]

combustion.

It is commonly known that fossil fuels are energy sources that are non-renewable [9,10]. Alcohol-based oxygenated fuels may have been regarded as one of the renewable solutions, with a potential to be used in a near CO_2 neutral manner through efficient conversion of biomass [11,12]. Alcohols have a long history of approximately 100 years as fuels in internal combustion engines (ICE). Alcohols such as ethanol, butanol, methanol, and fusel oil and ethers (MTBE and DME) are used as fuels in ICE [13,14]. First generation alcohols for spark ignition (SI) applications have so far largely based on gasoline-ethanol blends, where current fuel quality standards typically allow between 5% and 10% inclusions of ethanol within an existing gasoline pool.

Methanol was used as vehicle fuel during the 1930s to replace gasoline supplies in high-performance engine [15,16]. Butanol or butyl alcohol is four-carbon atom alcohol (C_4H_9OH) that can be used in non-modified spark ignition engines. It is miscible with most solvents and sparingly soluble in water [17]. Butanol is produced using fossil fuels, but can also be produced from biomass, in which case it is called bio-butanol. Both bio-butanol and petro-butanol have the same chemical properties [18,19]. Butanol quit similar to gasoline due to the longer hydrocarbon chain, lower oxygen content and higher heating value of butanol compared to methanol and ethanol [20]. Butanol can be used in non-modified spark ignition engines. Furthermore, in the 1930s, the government of Brazil stimulated gasoline blended with 5% bioethanol [21]. Due to the first oil crisis in 1973, Brazil decided to establish the national alcohol program (NAP) to reduce its reliance on fossil oil [22]. In Germany, oxygenated fuel such as MTBE was used with gasoline since 1985 to improve octane value as well as to decrease engine emissions. Since that date, the use of MTBE has rose significantly and reached around 408000–453592.37 Metric Tons in 1997 [23,24]. While MTBE has been used as a gasoline additive in the U.S. by 1979, formerly it was used as an anti-knock agent to replace lead [25]. DME does not have a long history as a blending fuel or additive with gasoline in SI engine, but blending DME into SI engine seems a possible solution for enhancing the combustion and improving the engine thermal efficiency under normal operation conditions [26,27]. Ethanol was first submitted as an internal combustion engine fuel by the 1930s in the USA and became commonly used since 1970 [28]. Currently, ethanol is used as fuel, especially in Brazil, while in Canada, t USA, and India, also ethanol is used as a gasoline additive to increase the octane rating and

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