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Using fusel oil as a blend in gasoline to improve SI engine efficiencies: A comprehensive review

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Abstract

Alternative fuels are becoming important due to higher energy demands but with limited fuel supplies. Fusel oil is a by-product obtained through the fermentation of some agricultural products such as beets, cones, grains, potatoes, sweet potatoes, rice and wheat. Fusel oil can be used as a clean and high-efficiency spark ignition fuel with a reduced NO_x. The energy value of fusel oil is near to other alternative combustible types and the limited number of researches on the use of fusel oil as an alcohol derivative in spark ignition engines constitute to the base of this research. The literature relevant to fusel oil use was reviewed and summarized to demonstrate the viability of fusel oil as an alternative fuel from renewable energy source. The aim of this paper was to review the potential for the utilization of fusel oil as a candidate for an alternative fuel for spark-ignition engine, while also describing the production and utilization of fusel oil generally. The octane number and density of fusel oil present the most important properties that make fusel oil a candidate for an alternative fuel for SI fuel engines. It was observed that the octane number increased with the increase in percentage of fusel oil in the blend tests. It was also noted that when the fusel oil was used as a blend with gasoline, the engine torque was slightly increased and the volumetric efficiency and

specific fuel consumption also increased. The hydro-carbon (HC) and carbon monoxide (CO) emissions were averagely increased. Furthermore, knocking and nitrogen oxides (NO_x) were observed to decrease when fusel oil was used. On the other hand, negative effects occurred in the engine performance caused by the higher water content in fusel oil.

Introduction

Fuel efficiency and pollutant reduction are demanded by the combustion industry due to the high cost of fuel and also because of environmental regulations. Combustion is continuously predicted to be the most important method of generating energy for the next 30 years [1]. High thermal efficiency combustion technology and alternative fuels produced from local feedstock are possible long-term solutions [2], [3]. The transport sector continues to account for a large share of humanity's total energy usage, and the road transport sector is characterized by near-total reliance on fossil fuels. Nowadays, the transportation sector represents 13.5% of the global warming effects [4], [5], [6]. The scientists are starting to search for other alternatives for fuels and for sources of energy [7], [8], [9]. A lot of efforts are currently being taken worldwide to find alternative fuels which may meet our present and future demands for energy, without causing further global-warming effects. Alternative fuels that are currently in use and under consideration are all still carbon based.

The term ‘alternative fuel’ describes any fuel other than the conventional fossil fuels used in the transportation sector. Alternative fuels contain gaseous fuels such as natural gas (CNG, LNG), hydrogen, and propane. Furthermore, alcohols such as ethanol, butanol, methanol, methyl tertiary butyl ether (MTBE) and dimethyl ether (DME) are also alternative fuels [10], [11], [12]. Alcohol based fuels attract the attention of alternative fuel researchers. Several researchers have studied on the usage of alcohols directly as an alternative fuel or fuel additives in spark ignition engines. The lower heating values of alcohols are lower than gasoline; therefore, fuel consumption usually increases when alcohol is used as an alternative fuel [13], [14], [15], [16]. Yücesu et al. [17] observed that the ethanol blending with gasoline reduced the carbon monoxide (CO) and hydro-carbon (HC). Similar results were reached in several other studies [17], [18], [19], [20], [21], [22], [23]. The reduction in carbon monoxide (CO) and hydro-carbon (HC) emissions was generated by the wide flammability and oxygenated characteristics of ethanol. Furthermore, similar results were obtained when referring to the reduction in carbon monoxide (CO) and hydro-carbon (HC) emissions when using the methanol –gasoline blends [24], [25], [26], [27].

Engine efficiency is determined by the compression ratio in the spark ignition engines. The ability to increase the compression ratio depends on the octane number of fuel used. Nowadays, limiting the octane number to less than 100 prevents the increase of compression ratio in spark ignition engines. For this reason, the efficiency of spark ignition engines is lower than compression ignition engines. A higher octane number can permit important increases in the compression ratio (CR), as in hydrogen and alcohol. One of the major ways to raise the efficiency and reduce the fuel consumption of an engine is the increment in the compression ratio. The addition of any fuels that have a high octane number to gasoline is essential in order to prevent knocking problem which occurs at higher compression ratios [28], [29], [30]. Abdel Rahman et al. [31] concluded on the different gasoline- ethanol blends of E10, E20, E30, and E40 with different compression ratios of 8:1, 10:1 and 12:1. The maximum indicated power was obtained with the compression ratios of 8, 10 and 12 MN for E10, E20 and E30 fuels respectively. Similar results were obtained by Çelik et al. [32].

Several additives can be added to gasoline to enhance the engine performance and combustion efficiency [33], [34]. The additives of high-octane oxygenated fuel to gasoline are very significant. Palmer 1986 [35] claimed that the addition of ethanol to gasoline led to the increase of research on octane number (RON) by 5 units for each 10% ethanol addition. He also indicated that adding 10% ethanol into gasoline as a fuel additive enhanced the engine power by 5%. Brinkman et al. [36] stated that the motor and research octane numbers increased due to increasing the methanol quantity in the fuel blend. Al-Hasan [19] examined the influence of ethanol–gasoline fuel blends on the performance of a spark ignition engine. The results presented that when ethanol was added to gasoline, the volumetric efficiency, brake thermal efficiency and brake power increased by 9%, 7%, and 8.3%, while air–fuel equivalence ratio and the brake specific fuel consumption BSFC decreased by 3.7% and 2.4% respectively. Taljaard et al. [37] conducted a study to review the influences of oxygenate in an SI engine. They measured the engine performance and emissions in a single cylinder for a stroke engine. It was concluded that the CO, NO_X and HC emissions decreased significantly at stoichiometric air/fuel ratio while oxygenates were utilized. Bilgin et al. [38] described an increase in the brake mean effective pressure with 5% methanol additive to gasoline. Mustafa Kemal et al. [39] investigated the influences of methanol, ethanol and gasoline fuel on the engine performance in an SI engine. They indicated that the torque and specific fuel consumption (SFC) were slightly increased when they used ethanol and methanol, compared to gasoline. They described that the increase in fuel consumption and engine torque could be the result from an improved combustion efficiency and lower energy value of methanol and ethanol. Similar results were obtained by Hsieh et al. [20], [40].

Fusel oil is a by-product of alcohol manufacture with fermentation through the process of distillation. It is also considered as a natural source of amyl alcohols. Fusel oil contains

primarily n-propyl alcohol (15–20%), iso amyl alcohol (55–60%), isobutyl alcohol (6–8%), bits of n-butyl alcohol and ethanol [41], [42]. Fusel oil can be used as a supply of energy for processing plants in addition to many other uses. The physical and chemical properties of fusel oil show that it may be used as a candidate for an alternative fuel for SI engines or as a fuel additive with gasoline to improve the fuel octane number.

There are a limited number of researches focusing on the effects of fusel oil as fuel blends on engine performances and emissions. This paper reported the details of fusel oil as a candidate for an alternative fuel for spark ignition engine that may potentially be used widely in the future as fuels blend with gasoline. Furthermore, the current study investigated the effects of performance (brake power, BSFC, EGT) and emissions (CO, NO_x, HC) characteristics of spark ignition engine with fusel oil. It also reviewed the production and utilization of fusel oil.

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Fusel oil production

Fusel oil is a by-product obtained through the fermentation of agricultural products such as beets, cones (sweet molasses), grains, potatoes, sweet potatoes, barley, rice and wheat [43], [44], [45], [46], [47]. The molasses are presented as one of the main products of sugar manufacturing that contain nearly 50% sucrose and 50% of other components. Because of its high sucrose content, a substantial portion of the molasses is used for the manufacture of ethyl alcohol during the fermentation…

Utilization of fusel oil

Fusel oil includes mainly three alcohols: ethyl alcohol, i-butyl alcohol and i-amyl alcohols as shown in Table 3. Various unpleasant properties of fusel oil may be removed and a substantial portion of the major alcohol components can be separated by a simple distillation. Fusel oil is considered as a natural source of amyl alcohols [53]. The i-amyl alcohol is obtained by the distillation of fusel oil. This product also consisted of a mixture of isoamyl alcohol and isomers active amyl [66], [67]…

Current application status of fusel oil

Fusel oil cannot be discarded directly into the environment, since it would cause undesirable environmental impacts. Some authors had indicated that with the direct applications of fusel oil, it can be burned to supply energy in the distilleries or it can be added to diesel fuel to improve the cetane index. Considering the amount of fusel oil in Brazil, a plant capable of producing isoamyl alcohol from fusel oil obtained from different distilleries is an interesting industrial application,…

The economics and the social acceptance of fusel oil

Renewable energy is one of the most efficient ways to achieve sustainable development. Increasing its share in the world matrix will help prolong the existence of fossil fuel reserves, address the threats posed by climate change, and enable better security of the energy supply on a global scale. Most of the new renewable energy sources are still undergoing large-scale commercial development, but some technologies are already well-established. These include fusel oil, which, after several years…

Properties of fusel oil

Fusel oil is the simplest alcohol with a low carbon-to-hydrogen ratio (C: H) and a chemical formula of $C_5H_{12}O$. The water content or concentration has a huge influence on the physicochemical properties of alcohol fuels [85]. Fusel oil is flammable and non-peroxide forming in its pure state or in aerosol formulations. It is a clear and colorless to pale yellow liquid according to disagreeable odors. It also has less density than water and is insoluble in water. The physical properties of fusel…

Blending fusel oil and gasoline

Gasohol is the name produced from mixing alcohol with gasoline. The using of gasohol blends appears to be the short-term solution to decrease pollutants, due to exhaust emissions and improved engine performance [116]. The advantages of fuel blends are that alcohol tends to increase the octane value and reduce carbon monoxide (CO) and other tailpipe emissions from the engine. However, the specific fuel consumption increases due to the low energy value of alcohol [117]. The octane number of a…

Phase separation temperature

Gasoline -alcohol blends are, indeed, a three-component system of alcoho1, gasoline and water due to the hygroscopic character of the alcohols. The most significant problem in

utilizing blends such as engine fuel is their potential separation into two liquid phases due to several factors such as water content temperature, alcohol content of the blend, and composition of the gasoline. Therefore, in the evaluation of alcohol gasoline blends as a fuel of SI engine, the initial step has to be…

Engine performance and emissions

Fusel oils such as ethanol and methanol exhibit the behavior of alcohol. When fusel oil is added to gasoline, allphysicaland chemical properties will change as mentioned above. All these properties have an effect on the performance and emissions of spark ignition engine. It is known that the oxygen content, the heat of vaporization and the water value of fusel oil like any alcohol fuels are more than those of gasoline fuel. That is why the volumetric efficiency of brake thermal efficacy…

Conclusion

Fusel oil is a by-product obtained from biomass such as sugar canes, beets, cones, grains, potatoes, sweet potatoes, rice, wheat, etc. The production of fusel oil from biomass sources involves the fermentation and distillation of crops. Fusel oil mainly included three alcohols: ethyl alcohol, i-butyl alcohol and i-amyl alcohols. Also, fusel oil can be used as solvents and supply energy for processing plants. Bio-lubricant could be prepared from fusel oil for many other uses. This study was…

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> ...Research dedicated to exploring possible uses of these materials is of great importance [40]. Fusel oil as a by-product can not be discarded directly into the environment since it would cause undesirable environmental impacts [78]. On the other hand, the negative point in the increase of biofuel (alcohols) production on environment presents by requires vast amounts of land and water resources....

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