

Fusel Oil as A Fuel Additive with Gasoline to Operate Spark Ignition Engine, A Comparative Review

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Abstract. The climate change, global warming, energy price, and energy supply crisis are the essential issues facing of the world. The petroleum based energy supplement was the main responsible for these problems. Alternative fuels need and the increasing of the sources of renewable and clean energy with limited fuel supplies are becoming important. Many students are studies alcohol as alternative fuels. From fermentation process fusel oil is produced as a byproduct with higher alcohol content. During the last decades, fusel oil is took care as a renewable fuel in spark ignition engine. The objective of the present study, is to survey the effects of fusel oil-gasoline mixture on the performance (break torque, break power, brake specific fuel consumption, efficiency, & effective) also on characteristics of combustion and emissions ((CO , HC hydrocarbons, NOx)) in SI engine.

Keywords: Fusel oil, Gasoline, SI engine, Additive, Blended fuel.

Introduction

The speedy reduction of depleting fossil fuels and ecological pollution have causes rising the need to use substitute fuel in (SI) engines [1]. Hence, biofuels produced of stuffs can be gained, that have higher thermal efficiency and lower exhaust emissions [2][3]. Alcohol based as alternate fuels presently widely reflected. Fusel oil is along series alcohol category sub-product of alcohol produced through the distillation process [4]. Its color is dark brown and its smell is bad. It has same properties of alcohol fuel like as higher (MON= 103), (RON=106), and solo ebullition point, also has high oxygen contented about (30.23)%, but fusel oil has high water content about (3-20)%. These properties articulate that fusel oil may be utilized as exchange fuel or as additive to gasoline for sparkle ignition (SI) engines[5][6]. Several studies have investigated fusel oil-gasoline mixture impact on the act of SI engine and emissions [7]. Research universities and organizations can play an important part in public approval and mainly in increasing the willingness to pay if it is necessary

for the fusel oil introduction into the energy market[8]. Alternative fuels are become important due to higher energy demands but with limited fuel supplies [9] .The aim of this survey is to indicate the most suitable utilization for fusel fuel in SI engine that achieve the best engine efficiency at maximum pollution protection. The different studies reviewed and classified in logical sequence and the different results compared to indicate the optimum engine performance criteria with diverse mixtures of fusel oil & gasoline.

Fusel oil production

Many fuels that containing alcohol (ethanol, butanol, and methanol) are traditional suggested as a renewable fuels in recent years[10]. Fusel oil quantity increased as by product when ethanol production rate has increased, which influence the consequent environmental. 1000 kg of sugar derivative of (sugarcane ,sugar beet) molasses produced about (523.8) L of ethanol[11], and one ton from ethyl alcohol produced about (6.4 L) from

fusel oil during process of distillation[12]. In world, fusel oil total potential production is about (550) million liters that will be equal about (347) million liter of gasoline. To calculate production of fusel oil, high concentrated geographically more than half products of worlds of fusel oil is in United state (54.36%), and Brazil (29.63%). In 2019, production of fusel oil was about 27 millions liters in European Union. In China, during 2009-2019 fusel oil production was around 17 million liters, and was the fourth in producing of fusel oil. Fusel oil had been greatly utilized over the last scarce years in several parts of the world. Furthermore, the estimates of the official cost for fusel oil are due to the many influencing factors such as the cost and availability of the raw material of fusel oil. As an example, in Turkey, the cost of fuel oil, gasoline and diesel are 1.7, 1.8, 0.82 \$ respectively, as shown in Table 2. The fusel oil costs in Turkey during a span of a few years received from Turkey sugar factories are detailed in Fig(2).

Table 1. Fusel oil composition.

Component	chemical formula	M.W
iso-amyl – alcohol	C5H12O	88.148
normal-butyl – alcohol	C4H10O	74.122
iso-butyl – alcohol	C4H10O	74.122
normal-propyl – alcohol	C3H8O	60.09
Ethanol	C2H6O	46.07
H2O	H2O	18

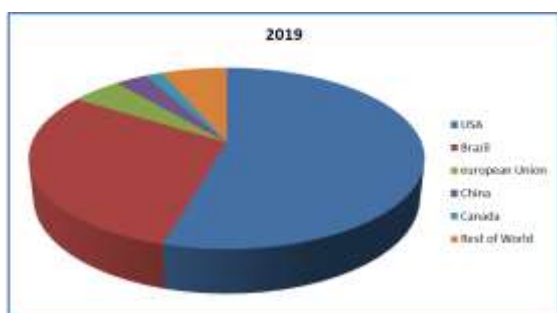


Figure 1. Production of fusel oil in world

Table-2 Comparative cost of fusel oil with diesel and gasoline in Turkey.

Fuel	Cost(\$/L)	Country	Source
Fusel Oil	0.82 \$	Turkey	Turkey Sugar Factories (A.S)
Gasoline	1.46 \$	Turkey	Shell
Diesel	1.23 \$	Turkey	Shell

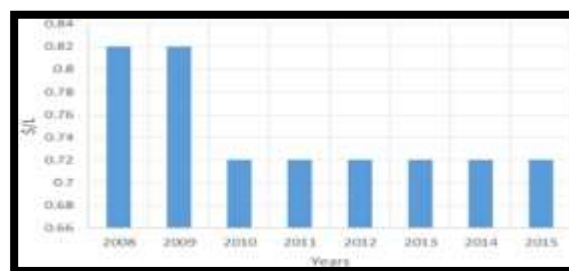


Figure 2. Fusel oil cost in Turkey during a few years

Fusel oil (physical & chemical) properties

Many Fusel oil physical and chemical properties are the central considerations for calculating qu for fuel after blending[13]. Table 2 presents conventional fossil fuel, diesel, gasoline, ethanol and fusel oil properties. Fusel oil has high oxygen contained which positive for combustion fineness and also on the other hand the high oxygen content decreases the heating value[14]. Besides, fusel oil utilization at high temperature is safe, because of auto-ignition temperature and flashing point of fusel oil are higher. Fusel oil has higher octane number compared to the ethanol [15]. Fusel oil has density more than ethanol density. Therefore, the rate of mass flow rise and fuel leakages decreases during injection[16], so the efficiency of fuel enhanced. Fusel oil has presence of water ranging from 3.5%-20% that cause a lower combustion, high heat rate which led to decrease NOx emissions[12]. Also fusel oil has a good impact on pressure of in-cylinder and timing of injection because fusel oils higher viscosity. Because of fusel oil physical and chemical properties, it can used as a new and an alternative fuel in SI engine.

Table 2. compare between Fusel oil and diesel& gasoline fuel(chemical and physical properties)

Parameters	Diesel	Gasoline	Ethano 1	Fusel oil
Oxygen cc	–	–	34.8	18
Density (kg/m ³)at 20 C	820	765	795	800.3
lower heating value(Mj/kg)	42.7	43.4	26.8	35.32
Octan number	30	99	100	98.7
Cetan number	55	10	8	42
latenet heat T 298 K (Kj/kg)	270	500	904	874
Flash point (c)	65	38	13	42
Stoichimometric AFR	14.3	14.7	9	–
Viscosity, (mm ² /s) at 40 °C	2.92 9	0.76	1.2	4.162
Auto ignition temperature, °C	~210	~300	434	416

Fusel fuel as additive

Many attempts has been conducted to investigate the utilization of fusel fuel as a pure fuel and fuel additive for operating SI engine. In 2012 Calam and Icingur used another fuel blend (10, 20, 30%) for operate spark ignition engine in different speed (2500, 3000, 3500, 4000, 4500, 5000) rpm under higher load conditions. The results revealed that the BSFC improved in all test conditions at a maximum value of about 7.7 % with F30, after the proportion of the fusel oil increased in mixture, engine torque decreased. Furthermore, in wholly fusel oil-blends, NOx emissions reduced compared by untainted gasoline for the reason that the reduction in engine exhaust temperature[17]. in 2013 Calam et al. studied on single-cylinder gasoline SI engine, they used another fusel oil mixing percentage (0%, 5%, 10%, 20%, 30% & 50%) with diverse load and stable speed of 3500 rpm. In this study the fusel oil introduced as a renewable fuel for SI engine because of its physical-chemical properties. The result showed an increase in BSFC and torque with a reduction in NOx [5]. In 2015 solmez Another study investigated fusel oil at adding ratio of (0, 50 and 100%) to gasoline. The results of the study was collected at speed of 2500 rpm and 4 load level of 25, 50, 75 & 100%. The results showed

that when fusel oil content increased the indicated mean effective pressure (IMEP) and heating value decreased because of water in fusel oil. Moreover, NOx decreased with 31% for F100 and the torque was decreased commonly into 6% and 2% at using of F100 & F50 fuel with addition of fusel oil ,while BSFC increased [18]. Suleyman & Bulent definite that, by adding of fusel oil in to pure gasoline, engine torque and SFC increased. Furthermore, when fusel oil quantity increased in the mixture, NOx, CO2 and UHC emission reduced[1]. Also in 2017 Omar presented a study showed the effect of water extraction from fusel oil on heating value and engine execution. The test steered on SI motor below 4500 rpm motors speed by using diverse mixing fraction of gasoline & fusel oil (G100, FBWE10, FBWE20, FAWWE10 and FAWWE20), engine execution and heating value were improved. The results shown that by increasing percentage of fusel oil in mixture, significant increasing in octane number of blended fuel is obtained[14]. In 2020 Calam presented a study showed the effect of adding fusel oil and gasoline blend percentage (20 ,40 & 60%) on composition and emissions of HCCL, the results shown that by increasing percentage of fusel oil in mixture NOx emission reduced, CO2 and UHC emission increased[3].In 2018 Simsek presented a study about adding fusel oil with percentage (10,20,30,40,50)% under load (1000-8000)(W) ,the results shown increasing in torque and BSFC, and decreasing in NOx, CO2,CO emissions[19]. In 2020 Simsek presented a study about adding fusel oil with percentage (30)% under load (1000-6000)(W) ,the results shown increasing in BSFC and torque, and decreasing in NOx, emission[20]. In 2019 Abdalla presented a study about adding fusel oil with percentage (10,20)% under speed (1500-4500)rpm, the results shown decreasing in torque and power and increasing in BSFC and decreasing in NOx[7].

Conclusion

Many A good appearance In SI engine of fusel oil has been presented for using as alternative fuel. Using of fusel-oil as an additive to gasoline advance the performance and emission levels at different loads. The speed and torque of engine are improved compared with pure gasoline. The study present an comprehensive review and show effect of using fusel oil in SI engine and the advantage of it as a new substitute fuel. Most important conclusion are summarized as follows;

- Fusel oil has high octane number that represent a promising feature to SI engines, Furthermore, the high density of the fuel results in increasing mass flow for fusel oil and gasoline mixture.
- Fusel oil addition to gasoline lead to increasing in torque, power of engine, effective efficiency and break specific fuel consumption (BSFC).
- Fusel oil has high moisture (water) content about 3%– 20% which worse combustion and caused bad effects in engine performance.
- Fusel oil has low harmful effect than petroleum fuel because it produced from biomass sources (it is renewable fuel) with low cost.
- Fusel oil has high carbon content, that led to increase HCL and CO emissions and reduces NOx emission in SI engine.s

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Competing Interests

The authors should declare that there are no competing interests.

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