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Scrutinizing the combustion, performance and emissions of safflower biodiesel–kerosene fueled diesel engine used as power source for a generator

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ABSTRACT

When neat biodiesel or its blends with diesel fuel that contain high amounts of biodiesel are used in diesel engines some operational problems such as poor injection, bad atomization and incomplete combustion occur mainly due to higher viscosity and surface tension. Engine problems with the use of biodiesel–fuel blends that contain higher percentages of biodiesel need to be solved in order to utilize the advantages of biodiesel in environmental and economical ways. The mentioned problems can also be solved by blending biodiesel with another low density or viscosity fuel such as kerosene. In present study biodiesel was produced from safflower oil. S90&K10, S75&K25 and S50&K50 were prepared by blending biodiesel with kerosene. A 4 cylinder diesel engine that was used to drive an electric generator was used to deeply investigate the similarity of combustion, performance and emission characteristics of the blend fuels to D2. All experiments were carried out at constant loads of 3.6, 7.2 and 10.8 kW generated powers. Patterns of combustion parameters found to be quite similar for blends and D2 fuel. NO_x emissions were considerably decreased with percentages of 68.2%, 56.9% and 55.1% for S50&K50, S75&K25 and S90&K10, respectively while unburned HC emissions were a bit increased. Mass fuel consumption and BSFC were slightly increased for S75&K25 and S90&K10, but they were decreased with an average increase in BTE by 3.84% for S50&K50 fuel when compared to D2. Eventually, it was concluded that high percentages of safflower oil biodiesel can be a potential substitute for diesel fuel provided that it is used as blended with certain amounts of kerosene.

1. Introduction

More than 80% of energy requirement have been supplied by fossil fuels until present and among them, oil contributed a good part. It has been reported that probably its use will not decline until the next two or three decades [1]. Since the beginning of this century researches have accelerated their works on alternative and renewable fuels. Vegetable oils and their derivatives have already been recognized to be main alternative fuels for diesel engines. But direct use of vegetable oils leads to some problems in engines. These problems are attributed to high density, viscosity, and poor volatility of vegetable oils. It is suggested that transesterification is the best way to use vegetable oil as a fuel in existing diesel engines [2,3]. Therefore, one of its inherent, biodiesel is derived from vegetable oils. Biodiesel has improved fuel characteristics such as viscosity, density and injection characteristics. However, it has still higher viscosity and density that exceed the limit values for standard diesel fuel [4,5]. Because, the surface tension and viscosity of biodiesel are higher it leads to poor atomization due to the increment in the mean droplet size of injected fuel jet. High surface tension cause to the lower Weber number that represent the lowered secondary deformation of the injected fluid that leads to the higher mean droplet size of injected biodiesel and eventually leads to poor atomization [6]. Namely, pure biodiesel or biodiesel–diesel blends with high percentages of biodiesel have also some operational problems in unmodified diesel engines. It has been reported that fuel properties of biodiesel and various engine designs result in different combustion behavior. However, even biodiesel is needed to be blended with normal diesel fuel in many cases. Many of engine manufacturer only permit the use of biodiesel with certain limits [7]. Only, some engine manufacturers announced that up to a 20% blend of biodiesel fuel can be used in diesel vehicles [8].

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Nomenclature

B100	neat safflower oil biodiesel
B75	75% safflower biodiesel in biodiesel–diesel blend
B50	50% safflower biodiesel in biodiesel–diesel blend
B25	25% safflower biodiesel in biodiesel–diesel blend
BSFC	brake specific fuel consumption
BTE	brake thermal efficiency
CAD	crank angle degree
CA10	crank angle position of 10% heat release
CA50	crank angle position of 50% heat release
CD	combustion duration
CHR	cumulative heat release
CI	compression ignition
CO	carbon monoxides
CO_2	carbon dioxides
D2	diesel fuel with 50 ppm sulfur content
DEE	diethyl ether
EGT	exhaust gas temperature
EOC	end of combustion (90% of heat release)
HC	unburned hydrocarbon
ID	ignition delay
HRR	heat release rate
JP-5	kerosene based aviation fuel number 5
JP-8	kerosene based aviation fuel number 8
K100	neat kerosene
K50	50% kerosene in kerosene–biodiesel blend
MGT	mean gas temperature
NOx	nitrogen oxides
NO	nitric oxide
PM	particulate matters
P_{max}	average peak pressure values of 100 cycles
RI	ringing intensity
S90&K10	the blend of 90% of safflower oil biodiesel–10% of kerosene
S75&K25	the blend of 90% of safflower oil biodiesel–10% of kerosene
S50&K50	the blend of 90% of safflower oil biodiesel–10% of kerosene
SOC	start of combustion (5% of heat release)
ULSD	ultra-low sulfur diesel fuel

The mentioned problems can also be solved by blending biodiesel with another low density or viscosity fuel. The problems of using pure or high percentages biodiesel blends is needed to be solved maybe by blending it with another fuel such as kerosene that has lower density, viscosity and distillation temperature. Even though, the cetane number of kerosene is lower which may cause to longer ignition delay period in combustion chamber its lower distillation temperature shortens ignition delay. Bergstrand [9] has also reported that the kerosene has lower cetane number than diesel, thus giving a longer ignition delay. Besides, if it will only be used as fuel additive in biodiesel in order to improve injection characteristics, the problem of longer ignition delay will not be faced. Furthermore, biodiesel has considerably higher cetane number that will compensate the lower cetane number of the blend and thus eliminate longer ignition delays for kerosene.

It has been reported that besides works on biodiesels, studies also maintain on different types of kerosene based fuels to adapt them for diesel engines and diesel power generators [10–13]. There are a few studies where biodiesel is blended with kerosene to test diesel and aircraft engines. Aydin et al. [14] investigated 20% kerosene and 80% cottonseed oil biodiesel blend in CI engine. They compared the emission results with that of diesel and cottonseed biodiesel blend. The purpose of using kerosene was to near the properties of biodiesel to diesel as reported. The effects of the blends on emissions such as NOx, CO, smoke and performance parameters were investigated. The prepared fuels, 20% kerosene and 80% cottonseed biodiesel, had similar fuel properties with petroleum diesel fuel. It was reported that for 20% kerosene and 80% cottonseed biodiesel the exhaust emissions were fairly reduced when compared to diesel fuel. Besides, the engine performance was said to be improved with the use of the 20% kerosene and 80% cottonseed biodiesel. They suggested that the 20% kerosene–80% biodiesel blend could be used as diesel engine fuel.

Performance and emissions of a diesel engine fueled with biodiesel–diesel, biodiesel–diesel-additive and kerosene–biodiesel blends have been investigated [15]. According to test results the BSFC increased with the increase of biodiesel in biodiesel–diesel-additive and in the blends of biodiesel–diesel. At medium and low load conditions CO emissions were considerably reduced with both biodiesel–diesel-additive and biodiesel–diesel blends. On the other hand, under all load conditions HC emissions were reported to be significantly decreased with the increase of biodiesel blends, while only under heavy loads kerosene–biodiesel blends were led to reduce HC. NOx emissions were reported to be reduced using kerosene–biodiesel blends at all load conditions. NOx emissions increased with the increase of biodiesel in the blends, under higher loads.

Arkoudeas et al. [16] tested a single-cylinder diesel engine operating with pure JP-8 and JP-8 fuel blended with 10 vol%, 30 vol% and 50 vol% of sunflower and olive oil. They found that using of both biofuels reduced PM emissions, but the HC and CO emissions almost did not change due to the added biodiesel. NO and NOx emissions decreased at low (10 vol%) additions, but the NOx emissions increased at high 50 percentages of biodiesel in the fuel blend. A study conducted on a single cylinder diesel engine at maximum torque speed of 2200 rpm and four loads with JP-8 fuel and sunflower methyl ester blends B25, B50 and B75 showed that the NOx emissions increased, but the CO emissions decreased as the amount of biodiesel fuel increased in the test fuels [17]. Experimental investigation of CI engine combustion, performance and emissions in DEE–kerosene–diesel blends of high DEE concentration has been conducted. 5%, 10% and 15% kerosene (by volume) were blended into diesel to investigate the adulteration effect [18]. As the percentage of kerosene blend increased the ignition delay was slightly increased. This result was expected due to lower cetane number of kerosene than diesel which leads to longer ignition delay.

The present work was carried out to evaluate the kerosene fuel along with its mixtures in biodiesel as fuels for diesel engines. The paper investigates the effects of certain amounts of kerosene–safflower oil biodiesel blends on combustion, performance and emission indicators in a diesel engine coupled with electrical generator. The problem that was aimed to be solved is to making possible the usability of high percentages of biodiesel in unmodified diesel engine. Comprehensive experiments were carried out to clarify the changes in test parameters when running the engine with mentioned test fuels. Furthermore, systematic investigations were conducted to analyze the effect of kerosene on biodiesel usage in diesel engine with high percentages.