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Effects of n-octanol as a fuel blend with biodiesel on diesel engine characteristics

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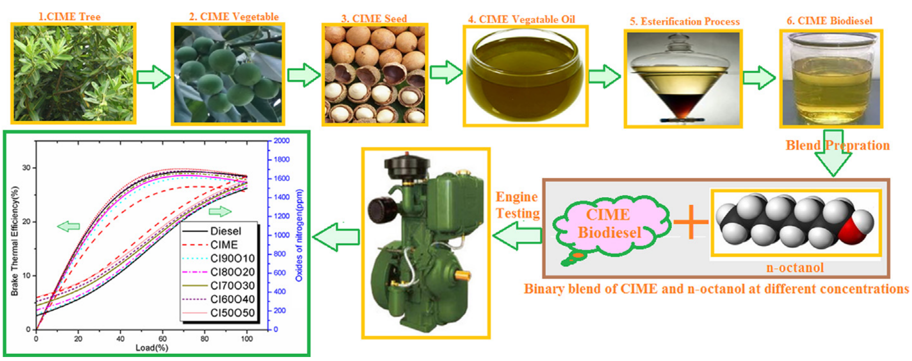
GRAPHICAL ABSTRACT



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ABSTRACT

Biodiesel can serve as possible alternate fuels in compression ignition engine as it leads to an effective reduction in consumption of fossil fuels. Moreover, it has been observed that biodiesel has the potential to reduce most exhaust emissions. The aim of the present study is to investigate the effect of n-octanol with Calophyllum Inophyllum biodiesel on compression ignition engine characteristics. Five different fuel blends are prepared by varying the concentration of n-octanol from 10% to 50% on a volume basis. It has been observed that the addition of n-octanol with biodiesel decreases the calorific value due to its inherent oxygen content. A mixed 6×5 level full factorial design with 3 replications was used for conducting the experiment. The statistical test by analysis of variance (ANOVA) revealed that CIME blend has the greater influence, contributing 71.3% to HC emission. The engine load has greatest influence of 98.88% to BTE followed by 98.77% to NOx, 95.74% to CO and 75% to peak pressure. The experimental results showed that the increase of n-octanol fraction in blends prolonged the ignition delay generating higher peaks of in-cylinder pressure and heat release rates during the premixed mode of combustion. Brake thermal efficiency has improved with the increase of n-octanol fraction up to 30% and then started decreasing with further increase of n-octanol in blends. Brake specific fuel consumption has reduced by about 20% with the increase of n-octanol fraction by 50%. Furthermore, the cooling effect produced by a lower fraction of n-octanol in the blend reduces the in-cylinder temperature resulting in lower NOx emissions. However, the poor ignition and evaporation characteristics of n-octanol has resulted in increase of CO and smoke emissions. HC emissions increase with the increase of n-octanol percentage due to the over-leaning effect of the excess oxygen content in the n-octanol. The higher fractions of n-octanol is beneficial in lowering the CO and smoke emissions because of enhanced combustion due to the presence of excess oxygen.

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Overall, the addition of lower fraction of n-octanol with biodiesel has enhanced the performance output with the reduction of NOx emission with noteworthy penalty in CO and HC emissions.

1. Introduction

The dependency of the fossil fuel resources and the necessity of reducing the greenhouse gas emission are the driving factors to look for the renewable fuel sources. Alternative fuels derived from biomass are the attractive options for the possible replacement of fossil fuels in the transportation segment. Biodiesel and bioalcohols are the primary alternate fuels for diesel engine applications due to their environmental and economic influence [1]. The countries with potential biomass sources are in the forefront in producing biodiesel and bioalcohols to meet their energy demands [2–4].

Biodiesel is produced from various feedstock sources such as oils, and animal fats through the process of transesterification. Recently, biodiesel derived from non-edible feedstock is gaining momentum due to the wider range of availability, environment friendliness, economical benefits and non-dependency on food crops [5]. Calophyllum Inophyllum is one such feedstock which belongs to Clusiaceae family and it is found in many parts of the globe [6–8]. The fuel properties of biodiesel obtained from the Calophyllum Inophyllum seed are comparable with that of diesel fuel and it can be fuelled in compression ignition engine (CI) without any major modifications. However, the lower calorific value and excess oxygen content in the biodiesel leads to the increase of fuel consumption and oxides of nitrogen (NOx) emissions as compared to that of diesel fuel [9]. In order to effectively utilize the Calophyllum Inophyllum methyl ester (CIME) obtained through the transesterification process, its fuel properties have to be modified by blending CIME with suitable additives. Since the higher alcohol properties are optimistic towards the performance characteristics from the engine and it can be blended with diesel or biodiesel to vary its properties [10]. Moreover, in the recent times the importance of using the higher alcohols in the CI engine is amplified due to its energy content and oxygen enrichment in the alcohol leads to provide an improved combustion results in the superior performance output [11]. As the carbon content in the higher alcohol increases the solvent capability, low polarity and less hygroscopic nature makes the easiness in the blending with diesel and biodiesels without any phase separations [2]. The term higher alcohol indicates that the number of carbon atoms in the straight chain is equivalent to four or more [12].

Reformulating the biodiesel with the help of higher alcohols like n-octanol is a viable option to enhance the properties of biodiesel in order to improve the performance in diesel engines. Octanol isomers are produced by means of various processes such as reversal of beta-oxidation, extending the 1-butanol pathway, rerouting branched-chain amino acid biosynthesis and biosynthesis of microorganisms like Escherichia coli and Clostridium species [13]. The fuel properties of the n-octanol such as cetane number, calorific value, lower vapour pressure and flash point are better over the other higher alcohols (< C8) makes a choice for the usage with biodiesels. The storage, handling and transportation of n-octanol is safe due to its very low vapor pressure (0.08 mmHg) [14].

In general, octanol fuel offers significant benefits either in the form of sole or blend mode, which provides higher calorific value, better auto ignition quality and phase stability as compared to lower alcohols. Hence, the consumption of the fuel to produce the same power output is insignificant [11]. Furthermore, the addition of n-octanol having higher oxygen content helps to reduce soot by promoting the oxidation of unsaturated hydrocarbon species. The higher oxygen molecules bounded by the fuel zone influences the combustion behaviour, which reduces the carcinogenic emissions from the CI engine [15]. There has been a lot of research work reported the positive features of the higher alcohols such as n-butanol (C4), n-pentanol (C5), and n-hexanol (C6). However, few limited work has been carried on the n-octanol as a blend with diesel and biodiesel for CI engine applications.

Kerschgens et al. [16] have analysed the combustion behaviour of C8 fuels in a diesel engine. The three different fuels used in the analyses are n-octane, n-octanol and di-n-buthylether (DnBE). All the fuels were tested on a CI engine and the emission results showed that the soot is very low and NOx emissions are within the acceptable range of Euro 6 norms. Also the fuel properties are not having the significant effect on the ignition and the reactivity of the fuels is affected by the mixture concentrations.

Zhang et al. [17] studied the steady state and cold start ability of a diesel engine fuelled with four types of higher alcohols blended with diesel fuel, which are isobutanol, n-butanol, 2-ethylhexanol and n-octanol. In addition, cetane enhancer such as hydro treated vegetable oil (HVO) or di-tertiary-butyl peroxide (DTBP) is added to the fuel blends. The addition of higher alcohol has improved the thermal efficiency, lowered the soot emissions but with the penalty of slightly higher NOx in the exhaust. Kumar et al. [18] carried the experimental work on using the n-octanol as a fuel blend with ultra-low sulphur diesel in three different ratios of 10%, 20% and 30% on a volume basis. For all fuel blend the ignition delay is higher than diesel fuel, which causes to generate higher peak pressure and heat release rate in the premixed combustion phase. Also, the thermal efficiency is increased for the higher fractions of n-octanol in the blend with reduced fuel consumption. The emission levels of NOx and smoke are reduced for the n-octanol blends with a maximum reduction of 8.8% and 32% is obtained for the 30% blend. Further, the experimental work is extended with the addition of exhaust gas recirculation (EGR) for all the n-octanol fractions and NOx reduction of 45.4% is obtained for 30% EGR with the loss of brake thermal efficiency (BTE). Zhang et al. [19] analysed the effects of n-octanol and butanol as a binary blend with diesel fuel in a single cylinder CI engine. The low boiling point of higher alcohol results in better fuel atomization and evaporation which leads to improved mixing of air and fuel inside the combustion chamber. This condition results in the comparable performance output of the higher alcohol blends with diesel especially with n-octanol. Further, the addition of higher alcohol exhibits lower soot and CO emissions with the penalty of increased NOx in the exhaust. This condition is attributed to the presence of higher oxygen content in the alcohol blends.

Some of the research works has been reported on 1-octanol as a fuel blend on the CI engine applications. Phoon et al. [15] reported the effects of 1-octanol blend with green diesel (5% palm biodiesel and 95% diesel) along with 2-ethylhexyl nitrate (2EHN) as cetane improver. The increased oxygen content by the addition of 1-octanol provides an enhanced combustion with higher thermal efficiency. Addition of EHN results in reduced NOx emissions with slightly higher fuel consumption as compared to that of green diesel. Deep et al. [11] investigated the effects of 1-octanol as a blend with diesel fuel in the ratio of 10%, 20%, 30% and 40% on a volume basis. The addition of 1-octanol fraction to the diesel fuel decreased the calorific value and increased the viscosity of the blend. The low blend ratio of 1-octanol resulted in reduced fuel consumption and this trend is reversed for the increment of octanol concentration in the fuel blend. NOx emission is decreased to be around 13.3% and 26.7% for 10% and 40% fraction of higher alcohol in diesel fuel. Hydrocarbon (HC) emissions of the 1-octanol blend are higher than that of diesel fuel due to the combined effect of higher heat of evaporation and cetane number. However, CO emission is found to be decreased for the higher alcohol blends and the maximum reduction of 23.8% is exhibited for 40% octanol blend at full engine load condition.