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Investigation on the performance and emission characteristics and influence of antioxidant on nitrous oxide emission in DI CI engine fueled by optimum papaya biodiesel blend

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ABSTRACT

Second generation biofuels are said to be compatible alternatives of conventional fuels due to their renewability and better combustion. Though higher proportion of biodiesel blends result in relatively less tail emissions when compared with their lower proportion blends and convention fuel, they resulted in poor performance. In the present investigation at the initial phase the blend B25 of papaya biodiesel, which is often identified as optimum in earlier investigation is employed to run a 5.2 kW DI CI engine at varying load levels. The seeds of papaya are cost effective feedstock for the production of biodiesel and the seeds contain about 35% of oil. Inspite of several advantages, in general biodiesel blends result in higher NO_X emission than the conventional fuel. The result outcomes revealed that, at full load the optimum blend performed better comprising brake specific fuel consumption of 0.280 kg/kWh and brake thermal efficiency of 31.44% along with enhanced NO_X emission ranging 988 ppm. In the later phase of investigation, Para-Phenylendiamine (PPDA), an antioxidant is employed in varying proportion to reduce the NO_X emission level and it is suggested that the proportion 0.250 g is found optimum in reducing the respective emission.

Keywords: *second generation biofuel, papaya biodiesel, performance, emission, nitrous oxide emission, antioxidant.*

Introduction

The rise of the transportation industry, agriculture, growth in industry, and several individual requirements all depend significantly on fossil fuels. Every day, the world's petroleum fuel reserves shrink. A significant number of researchers are therefore in search of alternate fuels. The reserves of fossil fuels have a greater appeal to renewable fuels [13]. Research on alternative fuel sources like biodiesels has raised due to factors including rising fossil oil prices, constrained fossil fuel reserves, and environmental concerns [14]. Biodiesel is a viable renewable source for replacement fuel of fossil fuels [8]. The need for using biodiesel rather than petro diesel is resilient, as it reduces the hazardous exhaust emissions from engines. However based on several studies, employing biodiesel fuel significantly increases engine-out NOx emissions [17]. The most harmful pollutant during the combustion stage is NOx. It is well known that the primary causes of NOx generation are higher combustion temperatures, longer burning times inside the combustion chamber, and oxygen concentration [18]. According to assessments of the literature, using 20% biodiesel in addition to diesel improves performance [9]. Due to the fact that its characteristics are identical to those of fossil diesel, biodiesel is considered as a renewable biofuel substitution. However, biodiesel's poor oxidation stability limits its storage stability. Therefore, chemical substances are added to the biodiesel to increase its oxidation stability [3].

Feedstock selection and processing

The papaya is a single stem plant, which has tendency to grow even in waste lands even with inadequate supply of water. This plant is especially grown for its fleshy fruits which comprises large number of seeds in its mid-portion. The second generation of biodiesel is more promising as it is made from non-edible resources instead of edible oils, which could reduce the dependency on food for fuels [11]. The seeds in general are discarded as waste, as it does not find any specific application. These waste discarded seeds are collected from the local available fruit vendors and are washed well with clear water to remove the presence of impurities. Followed by washing, the seeds are shade dried and winnowed to remove dust particles. With the help of mechanical extractor available in the local market, oil is expelled from the pure form seeds. The seeds are found to contain 35% of oil. The raw oil derived is found to be highly viscous and hence cannot be applied as fuel to run a DI CI engine. The photograph of feedstock employed is presented in figure 1 below.

Figure 1. Photograph of feedstock [16]

Chemical process employed

Transesterification is one among the chemical process which is said to be cost effective and conventional. Though this process results in comparatively less yield than the other chemical process, the purity of yield is quite better. In this investigation, this process is accomplished by employing a simple batch reactor provided with heating unit, stirrer and a thermometer. The reaction parameters are 60 ^{O}C of heating, 200 rpm stirring and the reaction period is 2 hours. This process results in two end products namely methyl ester and glycerol. The outcomes revealed that this process resulted in 82% of methyl ester yield. The glycerol due to its high density settles down and is eliminated by gravity separation technique. The photograph of simple rector employed in the present investigation is shown in figure 2.

Figure 2. Photograph of simple batch reactor [16]

Experimental engine

A 5.2 kW single cylinder diesel engine provided with a suitable tail gas analyzer, smoke meter and an acquisition system for gathering data. Throughout the test, engine is allowed to run constant at 1500 rpm. The test engine is water cooled and has a bore diameter of 87.5 mm and stroke length of 110 mm. The load to the engine is applied by the aid of electrically operating dynamometer in increments of 20% from zero to maximum. For initial standardization, the test engine is allowed to run for 10 minutes at no load. The performance and emission traits are determined after standardization initially with the conventional fuel and later with the optimum biodiesel blend. The trait values of optimum biodiesel blend is then compared with the conventional fuel. The photograph of the test engine employed is depicted in figure 3 below.

Figure 3. Photograph of test DI CI engine

Discussion on result

Performance and emission traits

It is known that DI CI engine is developed in constraint to operate better with conventional fuel and hence in order to deliver the rated power the fuel consumed by the engine is quiet high in case when biodiesel blends were employed. Nonrenewable fuels can be replaced with biodiesel fuel; up to 20% of the blend can be used as commercial fuel. But when the blend proportion ratio is high, the performance attributes deteriorate [7]. At peak load, the BSFC for conventional fuel and B25 POME are 0.257 and 0.280 kg/kWh. The conventional fuel comprises relatively less density when compared with the biodiesel blend and as a consequence results in better BSFC. The correlation between BP and BSFC for CF and B25 POME blend is depicted in figure 4.

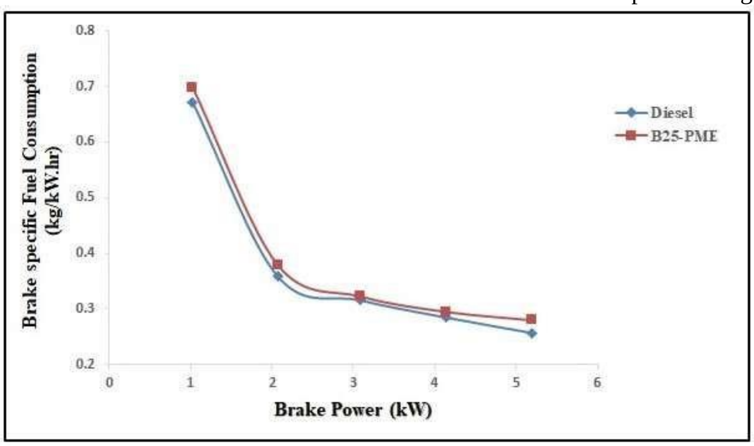

Figure 4. Variation of BSFC with BP

It is quiet common that the fuel with better BSFC results in better BTHE and as a result the conventional fuel delivers better BTHE (31.46%) when compared with B25 POME blend (31.44%). The reason for slightly declined BTHE for B25 POME is because of their high density and low calorific value. BTE is higher for standard fuel due to its heating value. Lower BTE of biodiesel blend is due to its lower calorific value and higher viscosity [2]. The variation of BTHE with BP for the test fuels is depicted in figure 5 below.

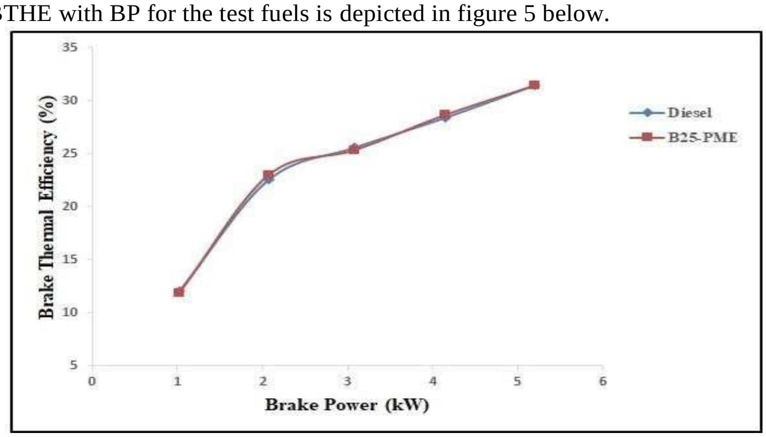

Figure 5. Variation of BTHE with BP

The biodiesels in common practice contains about 10% of oxygen and therefore results in better combustion. As the conventional fuel does not contain enough oxygen, it results in enhanced EGT ranging 321 ^{o}C, which is relatively high when compared with the value of B25 POME blend (318 ^{o}C). The variation of EGT with respect to BP is shown in figure 6.

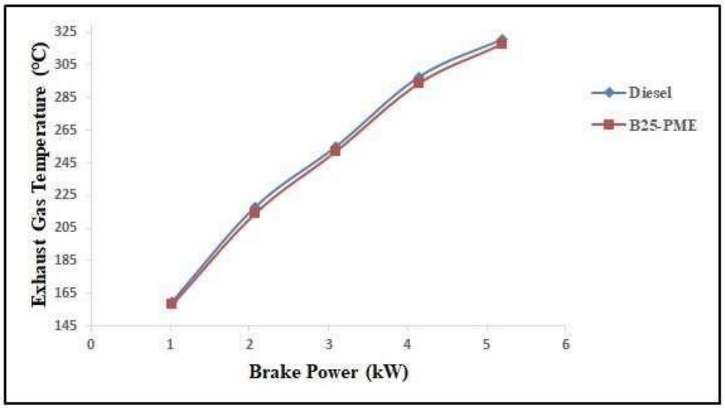

Figure 6. Variation of EGT with BP

Due to better rate of combustion, the level of smoke released at the time of combustion will be quiet less when compared with the conventional fuel. Moreover, the biodiesel blends does not contain sulphur or any aromatic compounds [4]. The SD of conventional and B25 biodiesel blend at full load are 50.62 and 49 HSU. The relation between BP and SD for test fuels is depicted in the below figure 7.

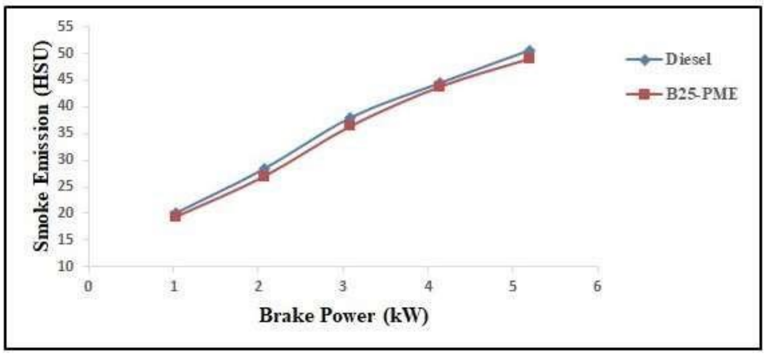

Figure 7. Variation of SD with BP

Biodiesels with adequate oxygen content promotes the rate of oxidation and as result of better oxidization, the formation of CO_2 takes place instead of CO. The formation of CO is mainly due to incomplete combustion and lack of oxygen molecules [1]. The CO emission at peak load for conventional and B25 fuel is 0.1 and 0.093 (% by volume). The biodiesel blends in common results in declined CO emission when compared with the conventional fuel. The correlation between CO and BP for conventional fuel and B25 POME blend is illustrated clearly in below figure 8.

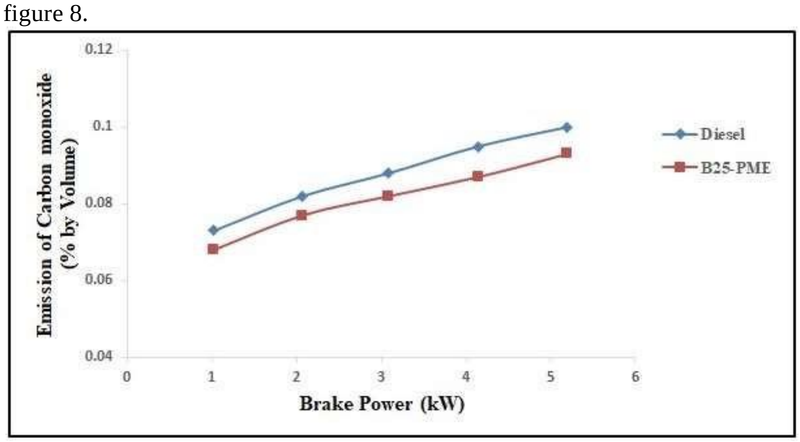

Figure 8. Variation of CO emission with BP

As a result of enhanced combustion due to the presence of oxygen molecules, the presence of unburnt fuel particles near the crevice zone is significantly reduced in the case where biodiesel blends are employed as fuel. In the present investigation, the B25 POME blend resulted in declined HC emission than the conventional fuel. The HC emission of B25 blend at peak load is 55 ppm, while that for conventional fuel it is 58 ppm. Utilizing biodiesel as fuel considerably lowers pollutants, including particulate matter, carbon monoxide, sulfur oxides, volatile organic compounds, and unburned hydrocarbons [12]. The variation of HC with BP for conventional fuel and B25 POME is depicted in below figure 9.

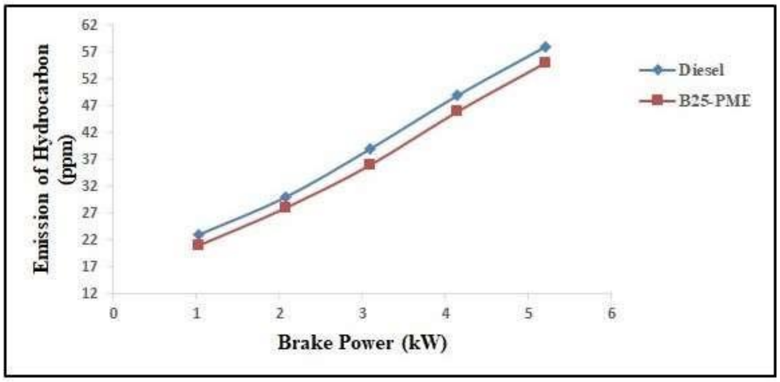

Figure 9. Variation of HC emission with BP

The presence of oxygen molecules in the biodiesel blend reacts with the nitrogen molecules of drawn air and results in the formation of enhanced NO_X. As the conventional fuel does not contain oxygen molecules, it emits relatively less NO_X (970 ppm) when compared with the B25 POME blend (988 ppm). The variation of NO_X with BP for the test fuels is shown if below figure 10.

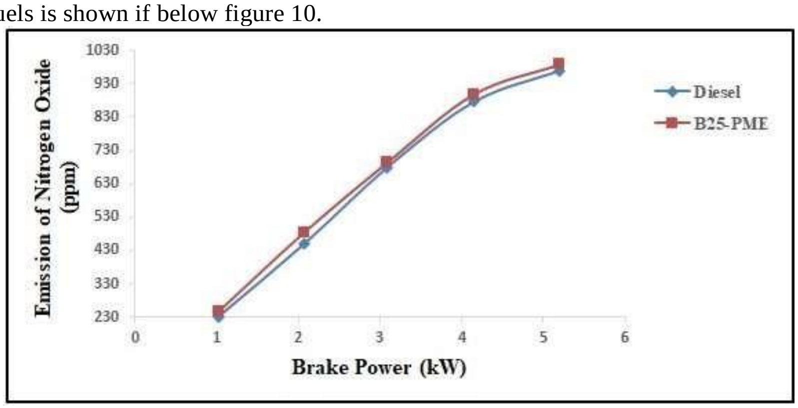

Figure 10. Variation of NO_X emission with BP

Influence of Para-Phenylendiamine in NO_X emission

In contrast to available techniques such as SGR and EGR, the incorporation of antioxidant agents is quiet compatible in declining the rate of NO_X emission. It was feasible to achieve variances in NOx levels in accordance with modifications in fuel compositions by incorporating antioxidants, despite utilizing cost consuming techniques such as EGR [6]. Introducing antioxidants in biodiesel blend is cost effective and does not require any additional setup. In the present investigation Para-Phenylendiamine is employed in varying proportions 0.05 g, 0.150 g, 0.250 g, 0.350 g and 0.45 g respectively to reduce the NO_X emission. Because of its potential antioxidant qualities, the PPDA efficiently removes free radicals during combustion, reducing NOx emissions significantly [9]. At maximum load the emission resulted by B25 POME blend along with 0.05 g, 0.150 g, 0.250 g, 0.350 g and 0.45 g are 960 ppm, 951 ppm, 939 ppm, 946 ppm and 974 ppm. From the investigation outcomes, it is determined that the 0.25 g proportion of PPDA resulted in declined NO_X emission, which is 4.95% less when compared with B25 POME without PPDA. Due to the composition and unsaturation concentration of different types of biodiesel and biodiesel blends, the additive concentration may change under various circumstances [5]. The reduction of OH radical generation by antioxidants lowers the combustion temperature and inhibits the production of peroxyl radicals, thereby lowering NOx emissions [10, 15].The variation in NOX emission for various concentration of PPDA is depicted in below figure 11.

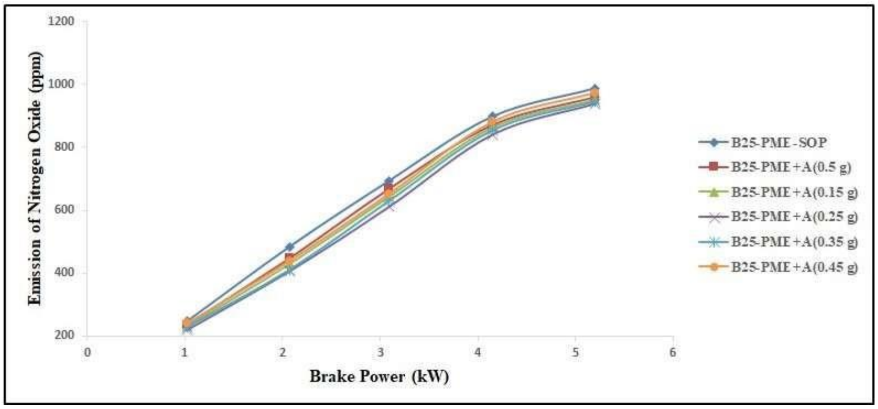

Figure 11. Variation of NO_X for varying PPDA concentration with BP

Conclusion

From the present investigation outcomes, it is suggested that the blend B25 can effectively be employed to run a DI CI engine as it comprises better BSFC (0.280 kg/kWh) and BTHE (31.44%). Furthermore, the EGT (318 ^{O}C) and SD (49 HSU) values of B25 POME is comparatively less by 3.24% and 1% when compared with the value of conventional fuel which is. In similar, the emission of CO and HC for B25 POME is found to be 0.093 (% by volume) and 55 ppm, which is 7% and 5.1% less when compared with the conventional fuel. Despite several advantages, the B25 POME results in enhanced NO_X emission, which is found to be 1.8% higher than the value of conventional fuel (0 ppm). The 0.25 g of PPDA performed better in declining the emission of NO_X and hence 0.25 g of PPDA is suggested to be optimum proportion. The incorporation of PPDA resulted in the decline of NO_X by 4.95% when compared with B25 POME without PPDA.

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