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Investigations on a diesel engine fuelled with biodiesel blends and diethyl ether as an additive

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Abstract: A single cylinder direct injection diesel engine was fuelled with blends of biodiesel and diesel at different proportions. The engine performance and emission characteristics were determined. The engine NO_X emission was noted to be higher than the diesel fuel operation with all blends. Diethyl ether was then added at different proportions to the blends. The addition of diethyl ether to the blends reduced the NO_X emission at low and medium loads; however, at high loads the NO_X emission was higher compared to diesel and lower compared to the corresponding biodiesel blend. The addition of diethyl ether to biodiesel blends reduced the both NO_X and smoke emission further.

Keywords: Biodiesel, diethyl ether, NO_X, Pongamia oil.

Introduction

The steady increase in energy consumption coupled with environmental pollution has promoted research activities in alternative and renewable energy fuels. Many countries in the world are continuously developing materials and methods for effectively utilising the alternative fuel resources available in their region. Among the various alternative fuels, biodiesel has received significant attention in recent years due to its environmental benefits. Studies have been carried out to find new biological resources for biodiesel production, and to utilise it as a fuel to run diesel engines.

Biodiesel is non-toxic and biodegradable. The combustion of biodiesel contributes less CO_2 to the atmosphere as it is captured by the growing plants for photosynthesis. Studies on using biodiesel as fuel in diesel engines have shown greater reduction in emissions of hydrocarbons, smoke, particulate matter, oxides of sulphur and carbon and polyaromatics as compared to diesel (Graboski & McCormick, 1997, Wang *et al*., 2000, Agarwal & Das, 2001, Kalligeros *et al.,* 2003, Ramadass *et al*., 2005; Hanumantha Rao *et al*., 2009; Hariharan *et al*., 2009). However, the studies on direct injection diesel engines have shown an increase in oxides of nitrogen (NO_X) (Serdari *et al*., 2000; Shi *et al*., 2005, Nabi *et al*., 2006). The NOx emissions are known to contribute to the formation of ground level ozone and fine particles that impair visibility.

Retarding fuel injection timing can reduce NO_X with a loss of some effectiveness for particulate matter reduction and a loss of fuel economy. The other approach to reduce NO_X emissions to a level equal to that from conventional diesel engine is to increase the cetane number of the fuel. Chemicals such as alkyl nitrates and certain peroxides can serve as cetane improvers. Serdari *et al*. (2000) used iso-octyl nitrate and a combustion improver for reducing the NO_X emissions from a single cylinder diesel engine fuelled with biodiesel. Szybist *et al.* (2005) used 2-ethyl hexyl nitrate as fuel additive in B20 blend to combat the NOx emission.

In the present work, the effect of adding diethyl ether (DEE) to biodiesel blends was studied. DEE can be produced by dehydration of bio-ethanol, a renewable fuel. DEE has long been recommended as a cold starting additive in diesel engines and gasoline engines due to its low autoignition temperature and high volatility (Gupta, 1988). The properties of DEE permit it to be used as a fuel for compression ignition engines; either as a neat fuel or as a blend with diesel. The auto ignition temperature of DEE is lower than diesel. DEE has a high cetane number of greater than 125. Its heating value is comparable to that of diesel. The latent heat of vaporization is higher than diesel. DEE is a liquid at room temperature which reduces handling and storage problems. DEE is also non-corrosive compared to alcohols. The properties which need concern are its high flammability and poor storage stability. DEE also poses human health problems due to its anaesthetic effect.

DEE as a fuel additive has shown to offer beneficial effects in terms of both performance and emissions. Anand & Mahalakshmi (2007) have showed that a 20% DEE in diesel along with 5% EGR result in the simultaneous reduction of smoke and NO_X emission. Recently, Ramadhas *et al*., (2008) studied the use of DEE as a fuel additive for reducing the cold starting problem and to improve the performance and emission characteristics of a diesel engine fuelled with biodiesel.

In this work, pongamia oil derived from the seeds of *Pongamia pinnata* is used to produce biodiesel. *P. pinnata* has been recognized as one of the most suitable among other plant species such as *Jatropha curcus and Madhuca indica* for producing biodiesel. The tree is tolerant to water logging, saline and alkaline soils; it can withstand harsh climates and planted on degraded boundaries of farmer's land or wastelands. It is one of the few nitrogen-fixing trees producing seeds containing 30-40% oil (Barnwal & Sharma, 2005).

In this work, the effect of adding DEE to biodiesel-diesel blends (B25, B50 and B75) and biodiesel (B100) were investigated. DEE was added in 10%, 15% and 20% (v/v) to the biodiesel fuels.

Materials and methods

The engine performance and emission studies were conducted on a Kirloskar make, single cylinder, direct injection diesel engine. The engine specifications are presented in

Table 1. Engine specifications

Engine type	Single cylinder, four stroke, direct injection, water cooled
Speed	1500 rpm
Bore x stroke	80 x 110 mm
Compression ratio	18.5:1
Rated power output	3.8 kW at 1500 rpm
Injection pressure	190 bar

Table 1. The engine was coupled to an electrical dynamometer and a resistance load bank to operate it under various loads. Two separate tanks of 5 liter capacity were used for storing diesel and biodiesel-blends with diesel. A fuel switching valve arrangement was provided to change over from one fuel to another while the engine was running. The fuel was fed to the injector pump under gravity and the volumetric fuel flow rate was measured by using a burette and stop watch. The exhaust gas temperature was measured using thermocouple connected to a temperature indicator. The exhaust emissions were measured by a smoke meter and NO_X analyzer.

The unrefined pongamia oil has a free fatty acid (FFA) content of 15%. A two step process was used to convert the high FFA oil into biodiesel (Canakci & Van Gerpen, 2001, Ghadge & Raheman, 2005, Ramadhas *et al.*, 2005). In the first step, 1% (v/v) sulfuric acid, an acid catalyst was used to esterify the FFA to methyl esters, thereby reducing the FFA level. In the second step, the low-FFA oil was transesterified with 0.6% (w/w) potassium hydroxide, an alkali catalyst to convert the triglycerides to biodiesel. The reactions were carried out in a 5 liter batch reactor for 1 hour at a temperature of 60°C.

The engine experiments were conducted with diesel fuel, biodiesel- diesel blends containing 25%, 50%, 75% (v/v) biodiesel (B25, B50 and B75 respectively) and biodiesel (B100). DEE was added to all the biodiesel fuels in proportions of 10%, 15% and 20% (v/v) and the impact on engine performance and emissions were measured. The fuel consumption and emission measurements (NOx and smoke) were taken under various loads and at constant speed.

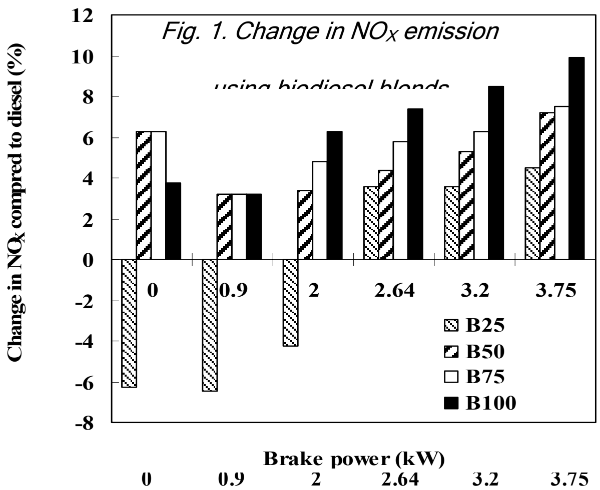

Fig. 1. Change in NO_X emission using biodiesel blends

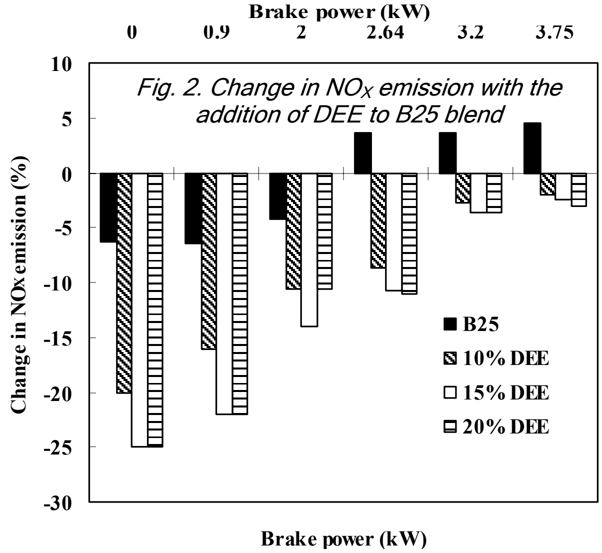

Fig. 2. Change in NO_X emission with the addition of DEE to B25 blend

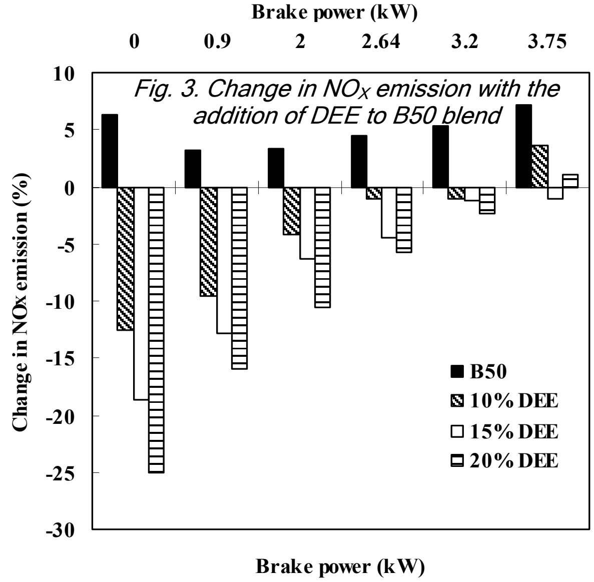

Fig. 3. Change in NO_X emission with the addition of DEE to B50 blend

Results and discussion

The NO_X emission from the engine using B25, B50, B75 and B100 as fuels were measured and compared with that of diesel. The percentage change in NO_X was calculated and presented in Fig. 1. It is seen that with increase in the concentration of biodiesel in the blend, there is an increase in NO_X emission. The NO_X formation depends on the availability of oxygen and combustion temperature (Heywood, 1988). The oxygen in biodiesel oxidizes nitrogen, thereby increasing NO_X emissions (Serdari *et al.*, 2000). It is seen from the results, B25 a blend containing the lowest concentration of biodiesel produces lower NO_X emissions compared to all other biodiesel blends due to its lesser oxygen content.

The impact of adding DEE to biodiesel fuels on NO_X emission is presented in Fig. 2 to Fig.5. The results indicates that, in general, the addition of diethyl ether to B25, B50, B75 and B100 decrease NO_X emission compared to diesel fuel operation. This result is expected as DEE is a cetane improver and any increase in cetane number decreases NO_X emission (Serdari *et al.*, 2000). Another reason may be the high latent heat of evaporation of DEE compared to either diesel (Huang *et al.*, 1999) which is beneficial to the NO_X reduction owing to the larger temperature drop of the mixture in the cylinder. The results also indicate that at high loads, there is no significant reduction in NOx emission with DEE addition to B25 blend. Also, at the same operating condition the NO_X emission using B50, B75 and B100 were higher compared to diesel fuel operation. This result was reasonable, since at high loads the combustion temperature becomes high which play a dominant role in the formation of NO_X. DEE added in proportions of 15% and 20% were found to give better reduction in NO_X compared to 10% DEE addition.

The results of smoke emission measurements are presented in Fig. 6. It is seen that, the smoke emission was reduced using biodiesel blends. The availability of oxygen in the biodiesel blends leads to better combustion and reduced the smoke emission. The smoke emission decreased by 2%,16%,23% and 26% using B25, B50, B75 and B100 blends respectively compared to diesel at full load.

The effect of adding DEE to biodiesel blends on smoke emission is presented in Fig. 7 to Fig.10. It is seen that the smoke emission reduced significantly by the addition of DEE to biodiesel blends. This may be due to the presence of oxygen in DEE. The addition of 15% and 20% DEE to biodiesel fuels was found to give significant reduction in smoke emission. The addition of 20% DEE to B25, B50, B75 and B100 blends reduced smoke emission by 13%, 23%, 34% and 36% respectively compared to diesel.

The results of engine thermal efficiency using different biodiesel blends are given in Fig. 11. With all the biodiesel blends, the thermal efficiency decreased marginally compared to diesel due to the lower heating value of biodiesel. Fig. 12 shows the effect of adding 20% DEE to biodiesel blends. The results indicate that the addition of DEE decrease the thermal efficiency maginally due to the lower heating value of DEE.

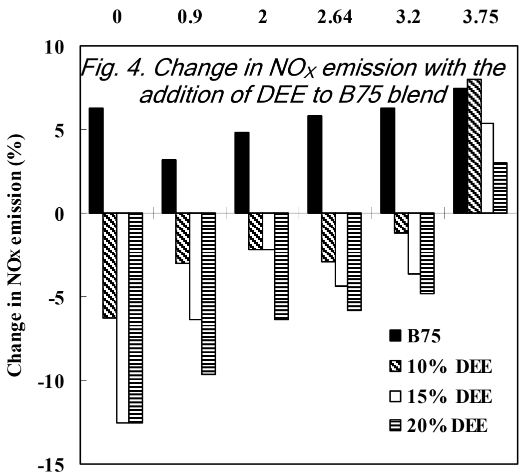

Fig. 4. Change in NO_X emission with the addition of DEE to B75 blend

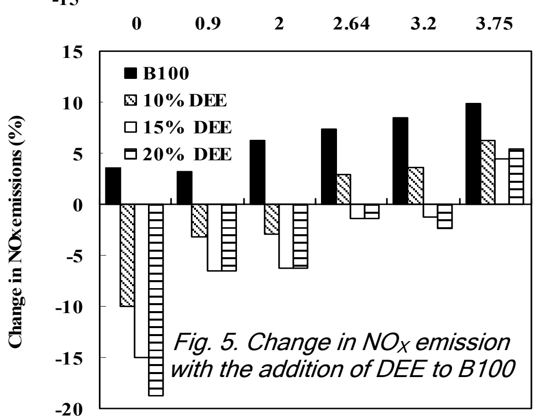

Fig. 5. Change in NO_X emission with the addition of DEE to B100

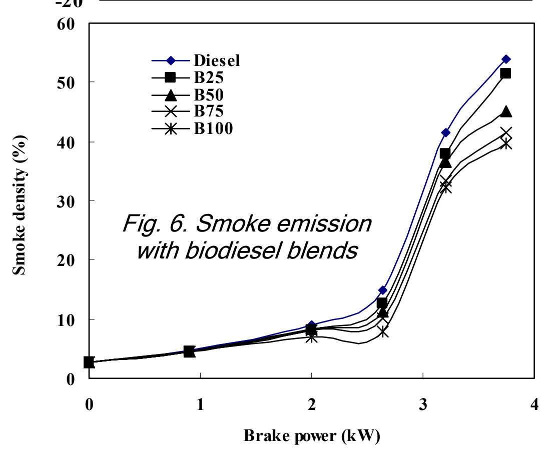

Fig. 6. Smoke emission with biodiesel blends

Conclusion

All the biodiesel blends produced a higher NO_X emission compared to diesel. With B25 blend, the NO_X emission was reduced by the addition of DEE at all load conditions. With B50, B75 and B100 blends, the NO_X emission was lowered by the addition of DEE at low and medium loads. However, at high loads the NO_X emission was higher relative to diesel; but lower compared to the corresponding fuel blend. The addition of 15% to 20% DEE was more beneficial in reducing NO_X compared to 10% DEE

The biodiesel blends tested showed a significant reduction in smoke emission. Further improvement in smoke emission was obtained by the addition of DEE. The addition of DEE resulted in a marginal deterioration of thermal efficiency. It is concluded that the addition of 15%-20% DEE to biodiesel blends would result in reduction of both NO_X and smoke emission.

Acknowledgement

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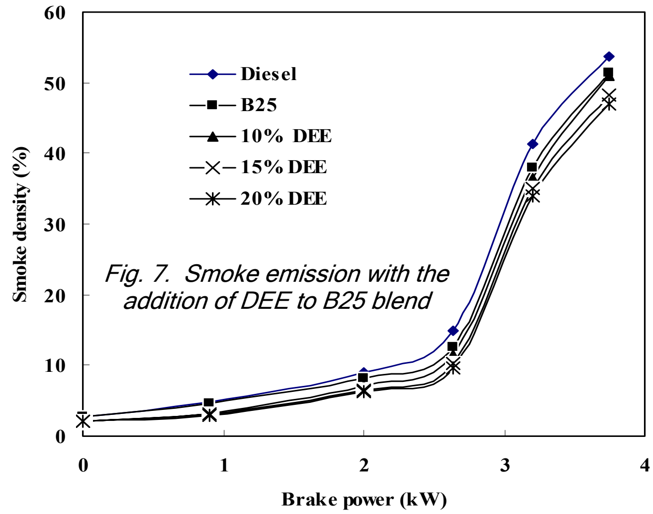

Fig. 7. Smoke emission with the addition of DEE to B25 blend

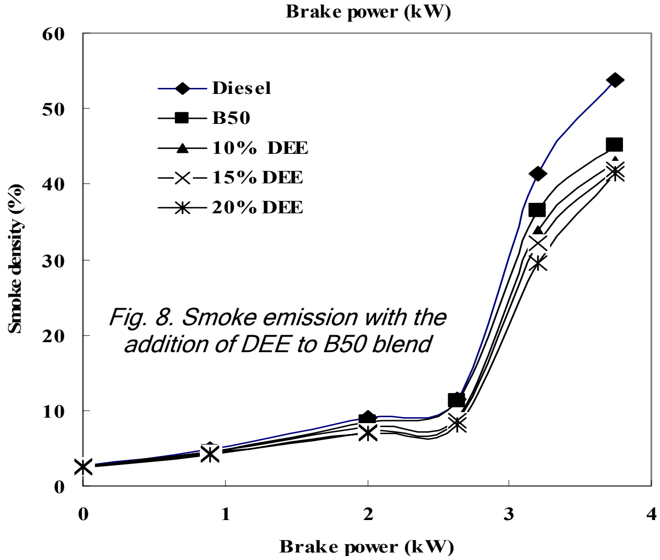

Fig. 8. Smoke emission with the addition of DEE to B50 blend

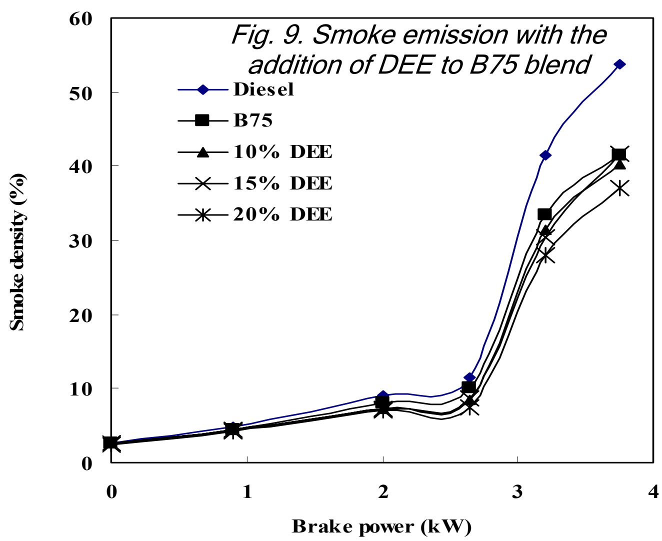

Fig. 9. Smoke emission with the addition of DEE to B75 blend

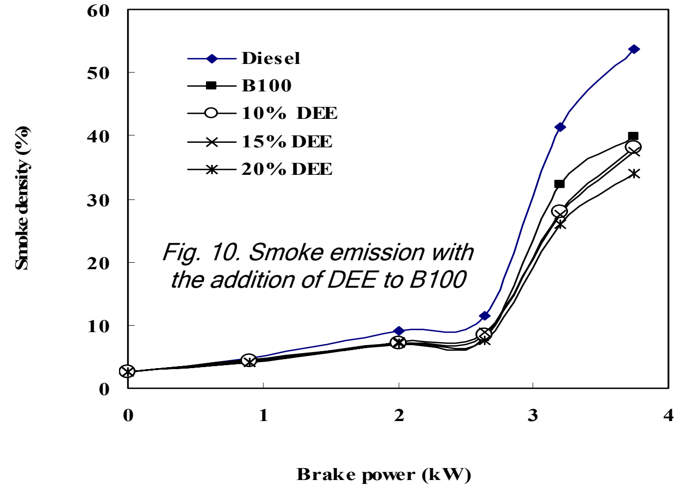

Fig. 10. Smoke emission with the addition of DEE to B100

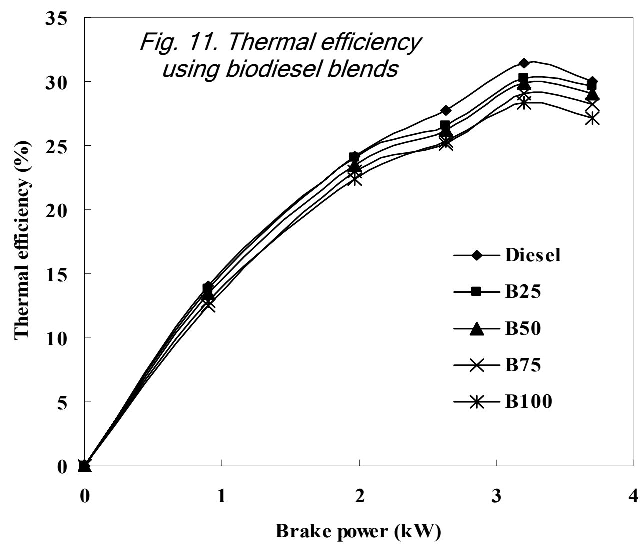

Fig. 11. Thermal efficiency using biodiesel blends

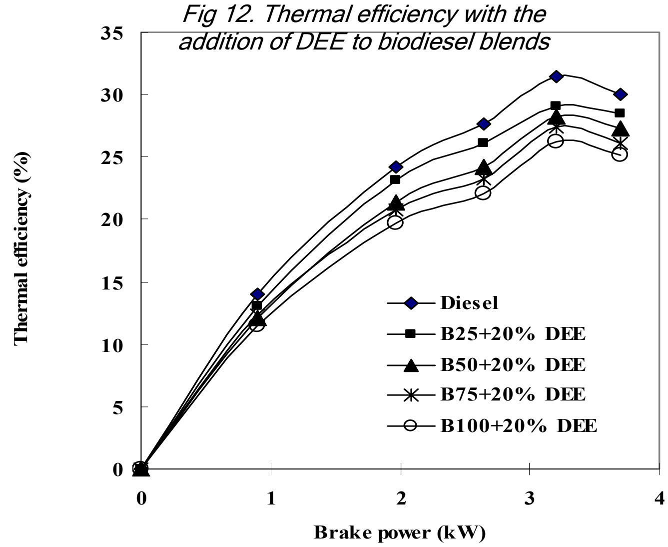

Fig 12. Thermal efficiency with the addition of DEE to biodiesel blends

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