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Effect of turbocharger on C.I engine performance and emissions using biodiesel blend

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Abstract

The scarcity of known petroleum reserves makes renewable energy resources more important. The most feasible way to meet this growing demand is by utilizing alternative fuels. Biodiesel is mono-alkyl esters of vegetable oils or animal fats. Biodiesel is the best alternative for diesel engines. The biggest advantage that biodiesel has over gasoline and diesel is that it is environmental friendly. Biodiesel burns similar to dieselas it concerns regulated pollutants. On the other hand, biodiesel probably has better efficiency than diesel. In the present study, Tamanu oil was selected as an alternative fuel which was produced by esterification and transesterification methods. The objective of the present study was to analyse the performance, emission characteristics in a single cylinder diesel engine with esterified tamanu oil and its blend with standard diesel. In addition to that turbocharger was fitted to the CI engine and their performance and emission characteristics were compared with and without turbocharger. The performance parameters indicated thermal efficiency, brake thermal efficiency, specific fuel consumption, volumetric efficiency and emission parameters included CO, CO_2, HC, and NO_x concentrations. The results of the experiment were analyzed and it confirmed to considerable improvement with turbocharger using biodiesel blend in the performance parameters, as well as in reduced exhaust emissions.

Key words

Biodiesel blend, CI engine, Emission, Performance, Turbocharger

Introduction

Biodiesel is an alternative fuel similar to diesel fuel. Biodiesel is produced from straight vegetable oil, animal fats, tallow and waste cooking oil. The process used to convert these oils to biodiesel is called esterification and transesterification. The largest possible source of suitable oil comes from oil yielding crops such as rapeseed, palm or soybean. Biodiesel can be produced from waste vegetable oil sourced from restaurants, chip shops, industrial food producers etc (Ani *et al*., 2011). Though oil derived from agricultural industry represents the greatest potential source and it is being started producing commercially because raw oil is cheap and the calorific value of biodiesel is more than diesel. Commercially producing biodiesel is less expensive than diesel.

Biodiesel has many environmentally beneficial properties. Biodiesel combustion decreases emission of carbon monoxide and unburned hydrocarbons. Increase in seed-to methanol ratio (within 40) can enhance biodiesel yield due to higher contact area between methanol and triglycerides (Pandey *et al*., 2012). Smoke and NO_X emissions are found less for all oxygenated fuel blends when compared to diesel fuels in the entire range of loads (Maher M Abou Al-Sood *et al*., 2012).The observations reveal that the test fuel blends are physically and thermally stable up to seventeen days at room temperature. The physio-chemical properties of the all blends show good resemblance with that of diesel, except for flash point (Balaji vignesh *et al*., 2012). In case where supercritical alcohol is used, it was demonstrated that higher reaction rate was achieved in esterification than transesterification.

Another advantage of this process was that the free fatty acid changed completely into esters (Manickam *et al*., 2010). Studies indicate that varying the compression ratio to achieve minimum brake specific fuel consumption and maximum brake torque for diesel engines should operate within maximum pressure and temperature (Asnida Yanti Ani *et al.*; Chao-Yi Wei *et al*., 2012). It has been proved that the brake thermal efficiency for biodiesel blend is higher than base line data of diesel and also there is considerable reduction in the emission of hydrocarbon, CO, NO_x and smoke when blends of bio diesel are operated with EGR technique (Marchetti *et al*., 2005). The CRDI engines with turbocharger run with biodiesel blends increases Break thermal efficiency, HC and CO emissions slightly varies with different fuels and the NO_x emissions increases at higher loads (Wang *et al*., 2010).

Literature studies indicate that the soot deposits on the engine components was found to be lesser by 21% in bio-fuelled engine which is due to improved combustion, whereas the soot deposit was found to be higher in diesel powered engine. Bio blended-fuelled engine after 100 hours of engine operation, the wear was found to be 11% to 50% lesser than those of the diesel-fuelled engine due to additional lubricity. Tamanu oil has been used in variable compression ratio engine without turbocharger resulting in increased volumetric efficiency, break thermal efficiency and decrease in overall fuel consumption (Mohan raj *et al*., 2012). A recent development in this area includes enzymatic esterification process with rice bran oil being converted in to biodiesel lowering the acid values and various beneficial health effects(Choi *et al*., 2015). In light of the above, the present study was carried out to analyse the performance and emission characteristics of a single cylinder diesel engine using biodiesel blend. The observations were recorded and investigated using tamanu oil diesel blend (B-10) and also the effect of installing a turbo charger on the engine were analysed for these parameters.

Materials and Methods

Vegetable oil was derived from Pinnai seeds (Pinnai oil) and its commercial name is Tamanu oil, methanol, acid catalyst (Concentrated H_2SO_4) and alkaline base catalyst (NaOH) KoH were used for esterification and transesterification processes to produce biodiesel.

For esterification process raw pinnai oil was mixed with methanol in the ratio of 300 ml of methanol for 1 litre of raw pinnai oil, about 50 ml of concentrated H_2SO_4 was added and heated up to 60^o to 65^o in a crucible and it was made to stir continuously for 3 hrs. The mixture was allowed to cool for more than 8 hrs. Glycerides were separated and mixed again with methanol in 5:1 ratio and was then to added alkaline catalyst to approximately 5 grams per 100 ml and heated up to 60^o to 65^o in a crucible with mild stir up to 90 min. The glycerines and biodiesel were separated after keeping in a conical separator for 4 hrs. Biodiesel was collected separately after draining the precipitated glycerine. Biodiesel was then washed 3 or 4 times using distilled water to remove the impurities to get pure biodiesel.

Experimental set up: A single cylinder four stroke water cooled Kirloskar engine of 3.5 kW power, having compression ratio of 18:1 with specially attached turbocharger of specification TEL 5435 101 4566-4 C5, was used with separate fuel tank for biodiesel. It was coupled with eddy current dynamometer through flywheel of the engine for varying the load in the multiples of 2 kg. The engine performance parameters were measured through load cell and sensors and emission parameters were measured using exhaust gas analyser interfaced with data acquisition system and analysed with the help of a computer. Exhaust gas analyzer was attached to the silencer to note the exhaust gas emission. Engine was started by using standard fuel and biodiesel blend (B-10) to measure the performance and emission characteristics.

Experimental procedure : The tests were conducted at the speed of 1500 rpm. In every test, exhaust gas emissions such as carbon monoxide (CO), hydrocarbon (HC), nitrogen oxides (NOx), carbon dioxide (CO_2) were measured. From the initial measurement, Indicated brake thermal efficiency (I.BTh.Eff.), Brake thermal efficiency (BTh. Eff.), Specific fuel consumption (SFC), Volumetric efficiency with respect to compression ratio (18:1) for B-10 blend (tamanu oil with diesel) were recorded.

Results and Discussion

The performance and emission characteristics of diesel engine run with biodiesel blend (Diesel with Tamanu oil) with and without turbocharger were analyzed and the results obtained are as follows.

Performance characteristics

Indicated thermal efficiency : The indicated thermal efficiency was steadly increased up to 60% with increase in load and decreased for the remaining load without turbocharger. The reason being the mixture strengh was optimum to release more heat during combustion upto 2.5 kgf. load. The indicated thermal efficiency then decreased with increase in load and remained constant till further increase in load, and was balanced with heat release rate at later stage of combustion process. It is well known that for turbocharged engine the thermal efficiency is cosiderably low due to dilution of mixture, which might be due to the excess air supplied to the engine, and the indicated thermal efficiency decreased with increased load. Variation in indicated thermal efficiency with respect to load is shown in Fig. 1.

Brake thermal efficiency: Variation in brake thermal efficiency with respect to load is shown in Fig. 2. The brake thermal efficieny was increased with increase in load, but it further increased for biodiesel blend with turbocharger, which might be due to complete combustion of oxygenated fuel and excess air supplied by turbocharger.The maximum brake thermal efficiency for B-10 was found to be 23% with turbocharger and 27% without turbocharger.

Specific fuel consumption : The overall specific fuel consumption decreased with increase in load for the turbocharger attached in the engine. The specific fuel consumption was very high zero load without turbocharger when compared with turbocharged engine. This was due to the dilution of mixture at zero load condition and the fuel required for combustion was slightly more during starting conditions. Variation of specific fuel consumption with respect to load is shown in Fig. 3.

Volumetric efficiency : It was clear from fig. 4 that the volumetric efficiency increased with increase in load for turbocharged engine. It was due to excess preheated air supplied by the turbocharger. The volumetric efficiency decreased with load due to the constraints in admitting air at high load operation. The advantage of using turbocharger in engine provides better diffusion of air fuel mixture. The combustion efficiency also increased due to increased turbulance in the combustion chamber.

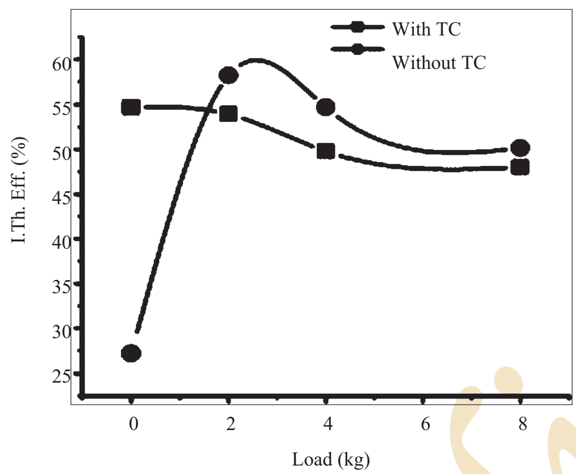

Fig. 1 : Load vs. Indicated thermal efficiency

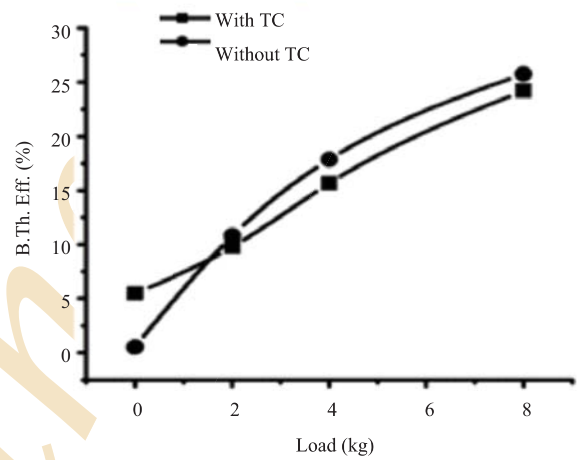

Fig. 2 : Load vs.Brake thermal efficiency

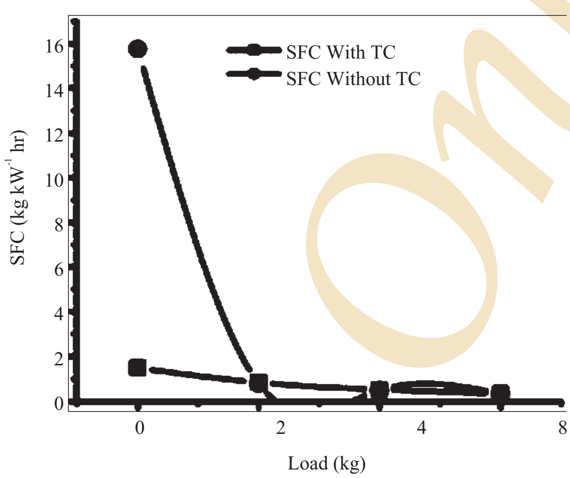

Fig. 3 : Load vs.Specific fuel consumption

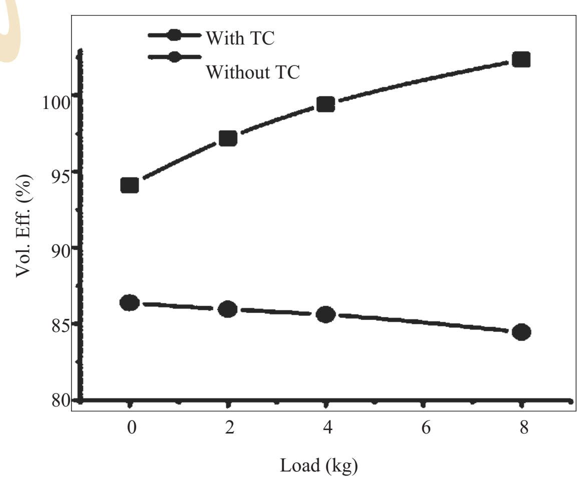

Fig. 4 : Load vs.Volumetric efficiency

Exhaust emission characteristics:

Carbon monoxide: Variation in CO emission with load is shown in Fig. 5. Emission of CO in CI engine with turbocharger was low when compared with engine without turbocharger. The reason being excess air supplied by the turbocharger attached in the engine which converts CO to CO_2. The emission of CO was 0.027% for maximum load and 0.010% for zero load conditions. It slightly decreased after 30% of load when it was used with turbocharger.

Carbon dioxide : Variation in CO_2 emission with load is shown in Fig. 6. The emission of CO_2 was more for B10 with increase in load with turbocharger. It was less without turbocharger. This was due to excess oxygen supplied by the turbocharger for combustion and CO was converted to CO_2 more than then the engine without turbocharger. The turbocharger supplies excess oxygen through forced induction which improves the oxidation of CO to CO_2 to approximately 1.6% more for turbocharged engine.

Hydrocarbon: Variation in HC emission with load is shown in Fig. 7. Emission of hydrocarbon was less for turbocharged engine run by biodiesel. In the absence of turbocharger ever hydrocarbon decreased after 2 kgf. of load in the engine. The combustion was effective due to excess of air supplied by the turbocharger and excess fuel with increase in load. Hence, hydrocarbon emission was decreased for turbocharged engine. Another reason for low hydrocarbon was that the biodiesel is an oxygenated fuel with less carbon content.

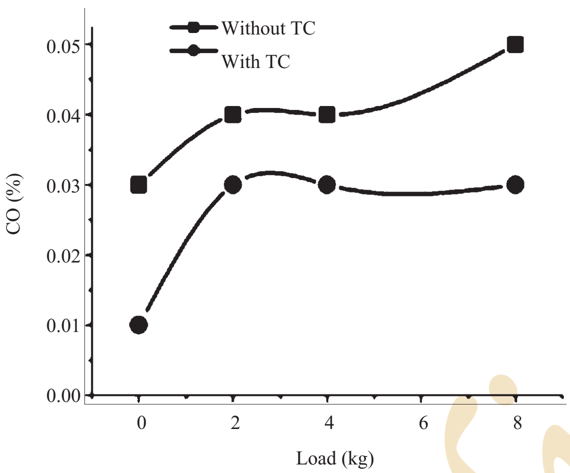

Fig. 5 : Load vs.Carbon monoxide

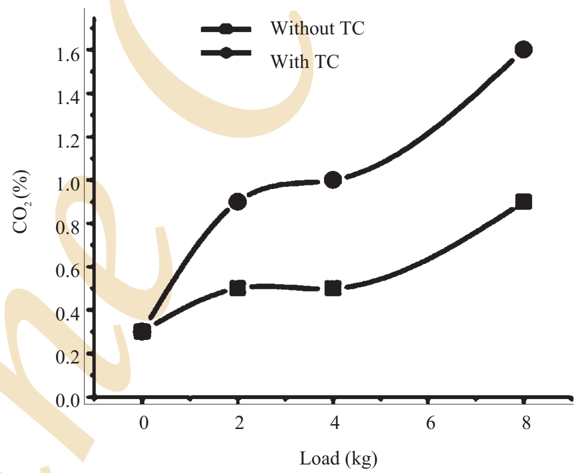

Fig. 6 : Load vs.Carbon dioxide

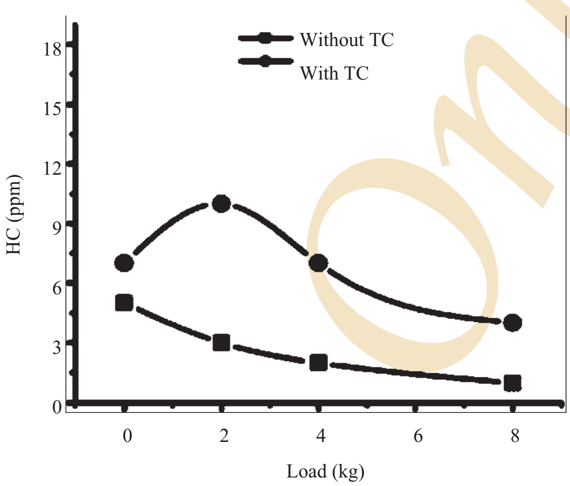

Fig. 7 : Load vs.Hydro carbon

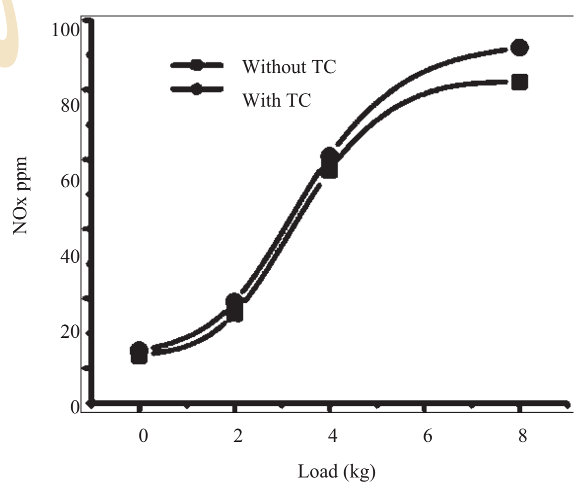

Fig. 8 : Load vs.Nitric oxide

Nitric oxide : Variation in NO_x emission with load is shown in Fig. 8. In general the NO_x emission was more for CI engine, but the effect of turbocharger considerably reduced the NO_x emission due to reduction in peak temperature in the engine, and another reason was due to dilution of air fuel mixture running with lean mixture combustion. For the increase in load with increase in thermal efficiency, the NO_x emission also increased without turbocharger. In comparision with turbocharger the NO_x emission was 80 ppm. and in the absence of turbocharger the NO_x emission was 90 ppm. for maximum load.

Compared with the previous research work in the present study, an optimum blend of 10% diethyl ether added with biodiesel resulted in a slight decrease in brake specific fuel consumption of 8.6%, while the brake thermal efficiency increased by 4.8%. Diethyl ether added to 20% biodiesel showed lower nitrogen oxide (NO_x) emission and slightly higher carbon dioxide (CO_2) emission as compared to diesel (Raheman *et al*., 2013). It is clear from the present study that biodiesel blend used in turbocharged engine have more benefits when compared with diesel.

It is concluded based on the engine performance and emission characteristics of biodieselused in turbocharged engine that the biodiesel blend (B10) gives better thermal efficiency and low exhaust gas emission with improved performance. The indicated thermal efficiency is considerably increased. The brake thermal efficiency and specific fuel consumption were optimum with increase in load for turbocharger. The overall emission concentrations were found to be low when using turbocharged engine. It was proved that the biodiesel blend (diesel with tamanu oil) could be used as an alternative fuel in diesel engines without major modifications.

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