Iranica Journal of Energy & Environment 3 (2): 109-117, 2012
ISSN 2079-2115
IJEE an Official Peer Reviewed Journal of Babol Noshirvani University of Technology
DOI: 10.5829/idosi.ijee.2012.03.02.0227

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Experimental Analysis of DI Diesel Engine Performance with Blend Fuels of Oxygenated Additive and COME Biodiesel

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(Received: January 25, 2012; Accepted: February 28, 2012)

Abstract: An experimental investigation was carried out to evaluate the effect of Triacetin (T) as an additive with biodiesel on direct injection diesel engine for performance and combustion characteristics. Normally in the usage of diesel fuel and neat biodiesel, knocking can be detected to some extent. By adding triacetin [$C_9H_{14}O_6$] additive to biodiesel, this problem can be alleviated to some extent and the tail pipe emissions are reduced. Comparative study was conducted using petro-diesel, biodiesel and additive blends of biodiesel on the engine. Coconut oil methyl ester (COME) was used with additive at various percentages by volume for all load ranges of the engine viz. at no load, 25, 50 and 75% of full load and at full load. The performance is compared with neat diesel in respect of engine efficiency and exhaust emissions. Among the all blend fuels tried, 10% Triacetin combination with bio-diesel shows encouraging results.

Key words: Biodiesel; COME; Exhaust emissions; Oxygenate additive; Performance; Triacetin

INTRODUCTION

The increasing in environmental pollution caused by the extensive use of conventional fossil fuels has led to search for more environment friendly and renewable fuels. Biofuels such as alcohols and biodiesel have been proposed as alternatives for internal combustion engines [1, 2]. In particular, biodiesel has received wide attention as a replacement for diesel fuel because it emits less pollution, renewable, environmental friendly and easily produced in rural areas [3,4]. It is also commonly accepted that diesel engine emission can be reduced effectively using oxygen content alternative fuels, or potentially the addition of oxygen within the diesel fuel. Therefore, much research has focused on screening of oxygenated fuel additives, including alcohols, esters and ethers to reduce emissions [5-7]. DMC (dimethyl carbonate) is an additive with the oxygen content of 53.3%, which is used as an oxygenated additive to blend with diesel fuel for the improvement of combustion and to reduce emissions of the diesel engines [8-10].

In the present work the performance of D I diesel engine is studied with coconut oil methyl ester and triacetin additive blends at different percentages. Normally additives are used to boost the combustion hence improves fuel economy at lower emission rates from the engine. NO_x emissions include high-pressure injection, turbo charging and exhaust after treatments or the use of fuel additives, which is thought to be one of the most attractive solutions [11-13]. Blends of diesel and biodiesel usually require additives to improve the lubricity, stability and combustion efficiency by increasing the Cetane number. Blends of diesel and ethanol (E-diesel) usually require additives to improve miscibility and reduce knock. Diesel additives can also be classified according to the purpose for which they are designed.

Pre-flame additives are designed to rectify problems that occur prior to burning and include dispersants, pour point depressants and emulsifiers, which act as cleaning agents. Flame additives are used to improve combustion efficiency in the combustion chamber, to increase cetane

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Table 1: Specifications of engine test rig

Engine manufacturer	Kirloskar Oil Engines Limited, India
Engine type	Vertical, 4stroke, Single cylinder, DI
Cooling	Water cooled
Dynamometer	Eddy current dynamometer
Rated power	3.7 kw at 1500 rpm
Bore/Stroke	80/110 (mm)
Compression Ratio	16.5:1
Injection pressure	200kg/cm^2
Injection timing	23° BTDC

number, to reduce the formation of carbon deposits, to avoid oxidation reactions and contamination of fuel and filters clogging by rust and to inhibit potential explosions caused by changes in static electricity [14]. Post flame additives are designed to reduce carbon deposits, smoke and emissions in the engine [15]. In diesel engines, the knock is audible noise that results from auto ignitions in the unburned part of the gas in the cylinder or initially accumulated fuel during the earlier phase of injection. The probable locations for harmful self-ignition lie in the proximity of hot surfaces such as piston, cylinder walls and at the largest possible distance from the spark plug or injector. This auto ignition is the result of chemical state of unburned gases exceeding a critical level in which enough of highly reactive radicals are formed, which leads to spontaneous ignition. This pre-reaction levels being proportional to the concentration of radical, that increases with time under the infuence of high temperatures and high pressures. This knocking can be prevented by the addition of additives in biodiesel fuel [16]. Triacetin can be used as fuel additives as an antiknock agent which can reduce engine knocking in gasoline and to improve cold and viscosity properties of biodiesel.

Experimental: The test rig details shown in Table 1 was used to conduct experiments with diesel, pure COME and COME with Triacetin [$C_9H_{14}O_6$] additive at different percentages of blends for full load range of the engine without modifications. Performance, exhaust emissions and smoke density parameters were measured using instruments indicated in Figure 1. Cylinder combustion pressures for each degree of crank angle were measured by engine data logger designed by Apex innovations, Pune, India. The software employed is C7112, which captures the combustion pressure data and converts it into the graphic form collecting crank angle history from the encoder and synthesizes with the real time pressure data. Fuel consumption is measured to calculate BSFC, fuel air ratio and thermal efficiency. Exhaust gas temperatures were also recorded for all loads. Delta 1600-L exhaust gas analyzer (German Make) is used to measure CO_2, CO, HC, NO in exhaust gases at all loads and graphs are drawn to analyze the emissions.

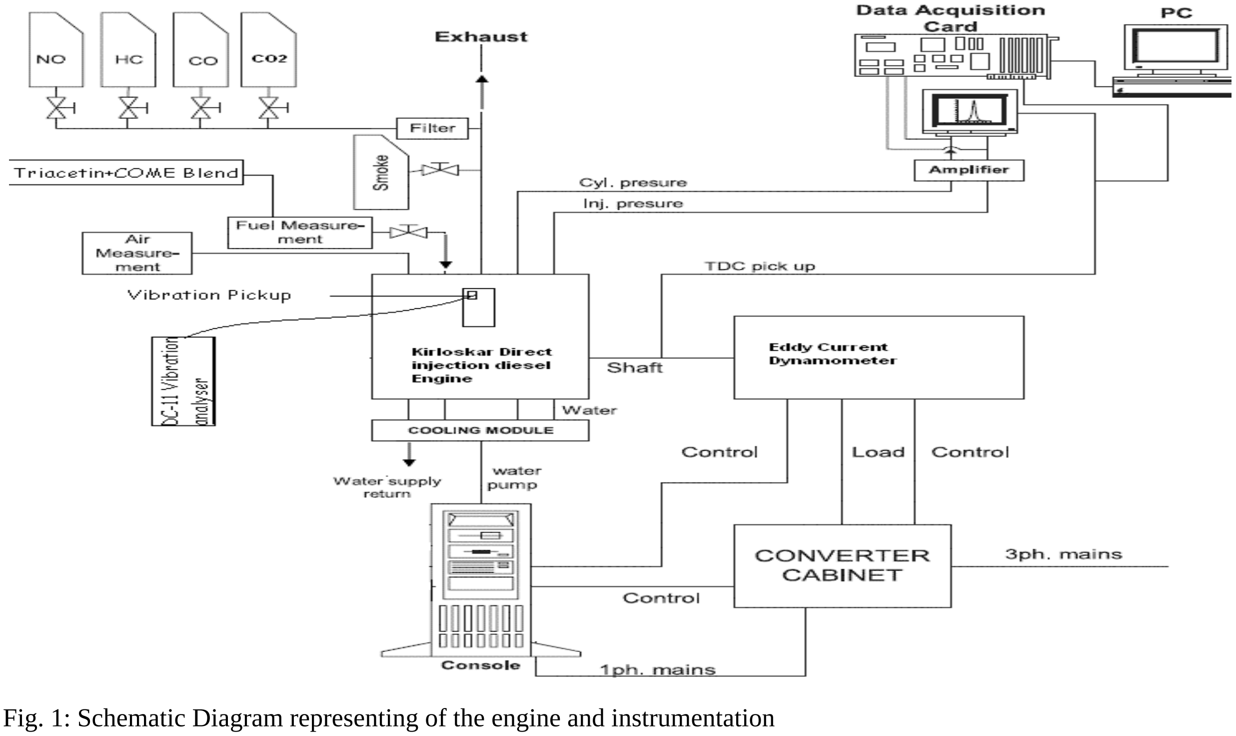

Fig. 1: Schematic Diagram representing of the engine and instrumentation

RESULTS AND DISCUSSION

Triacetin is soluble in biodiesel, mineral oils and aromatic compounds. Because this additive is an oxygenated compound and also is anti knocking agent in the case of gasoline engines, a trial was made to investigate the suitability to biodiesel additive. The basic engine performance was studied and observed that the brake specific fuel consumption (Figure 3) has increased with the higher percentages of triacetin, because its calorific value is lesser than that of biodiesel. Same is reflected in the case of thermal efficiency depicted in Figure 2. Since its boiling point and density is more than one and with the important property of converting ordinary biodiesel into second generation biodiesel with higher Cetane number in combination has reduced delay period. It contributed more for the refinement of premixed combustion than the diffused combustion. This is the reason that the exhaust gas temperatures are lesser with the addition of more triacetin quantity in the blend as presented in the Figure 4.

The 10% triacetin blend has generated new trend in the pressure profile as shown in Figure 5. This may be because of solubility criteria in the biodiesel tested within the better saturation limit. This percentage may not claim betterment presumably with the other biodiesel fuels. There is a resultant betterment in the blend's start of combustion and consequently telling on the pressure development. Even 75% full load operation is a testimony to this conclusion as shown in the pressure signatures in Figure 6. There is an isolated uniformity in the smart heat release rate with consistent uniformity through out the net heat release traces in Figures 7 and 8 for the advantaged blend of 10% triacetin. The cumulative heat release rates also envisage that constant performance of biodiesel as shown in Figures 9 and 10. It shows that 5% blend as the dullest blend with inefficient combustion propensity created by its presence.

In pollution graphs, the black stacks indicate absolute values and the remaining color stacks indicate the differential values with respect to

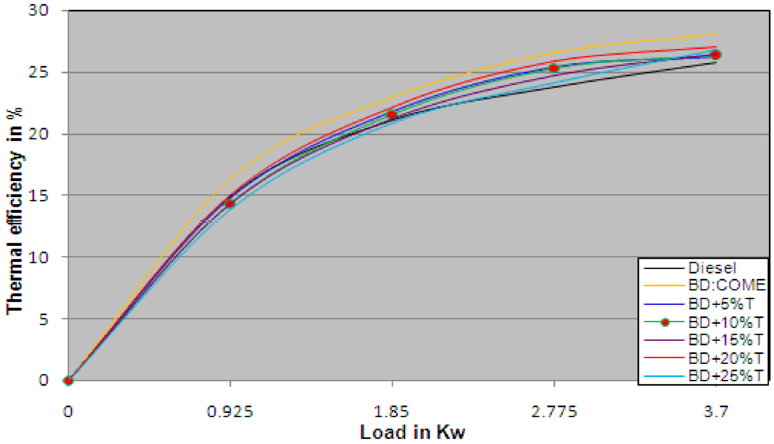

Fig. 2: Variation of brake thermal efficiency verses load on the engine

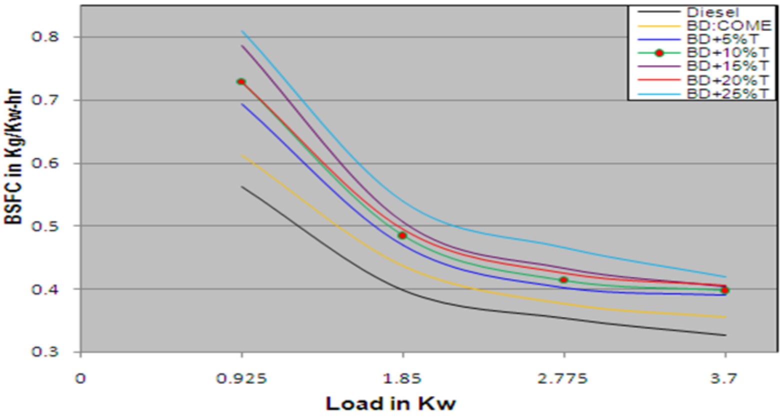

Fig. 3: Variation of bsfc verses load (brake power) of the engine

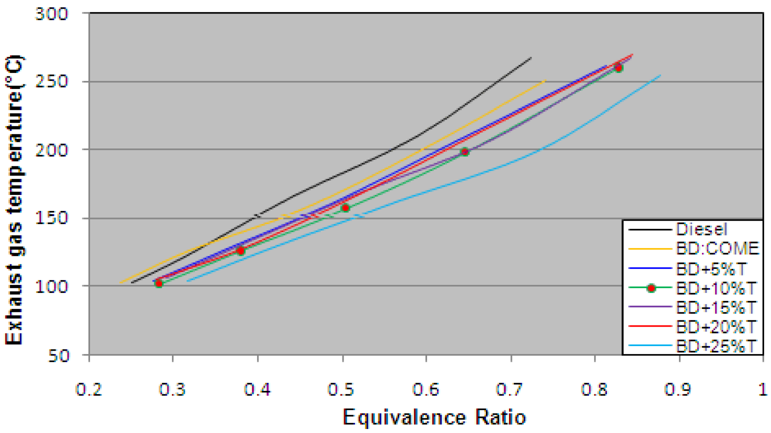

Fig. 4: Variation of exhaust gas temperature verses load on the engine

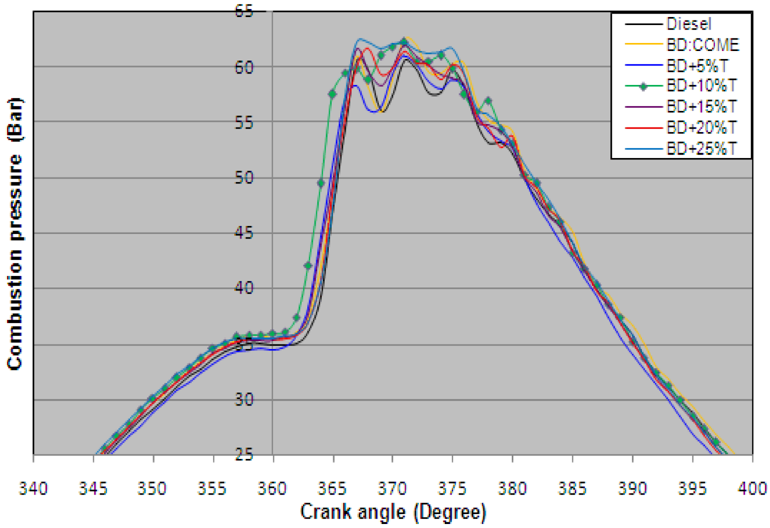

Fig. 5: Variation of pressure verses crank angle of the engine at full load

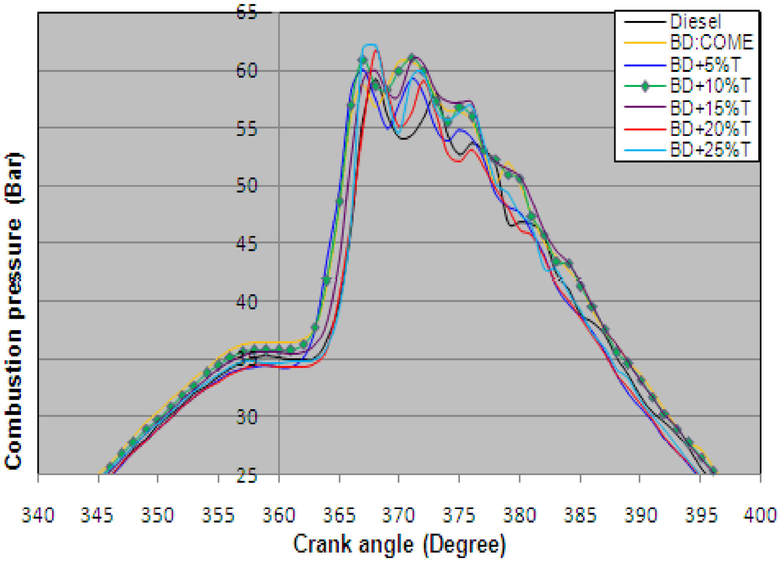

Fig. 6: Variation of pressure verses crank angle of the engine at 75% full load

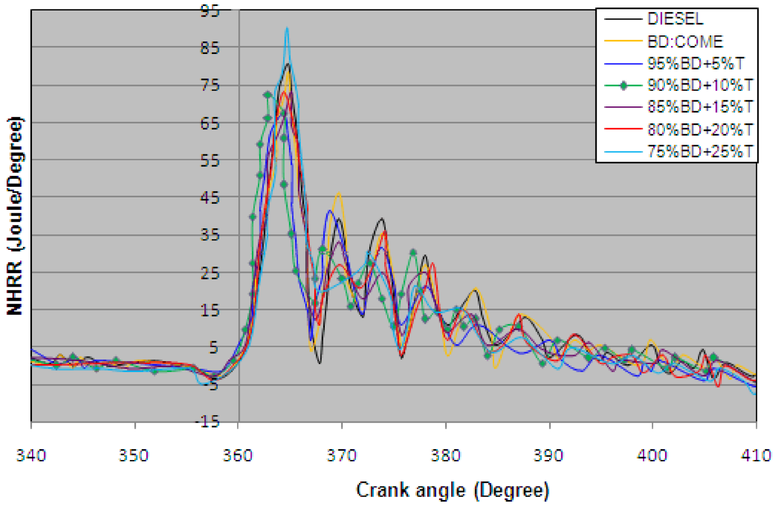

Fig. 7: Variation of net heat release rate verses crank angle of the engine at full load

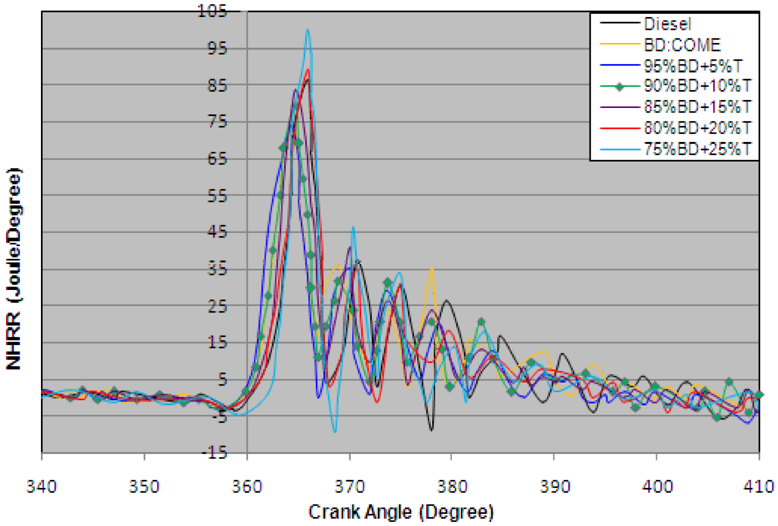

Fig. 8: Variation of net heat release rate verses crank angle at 75% full load

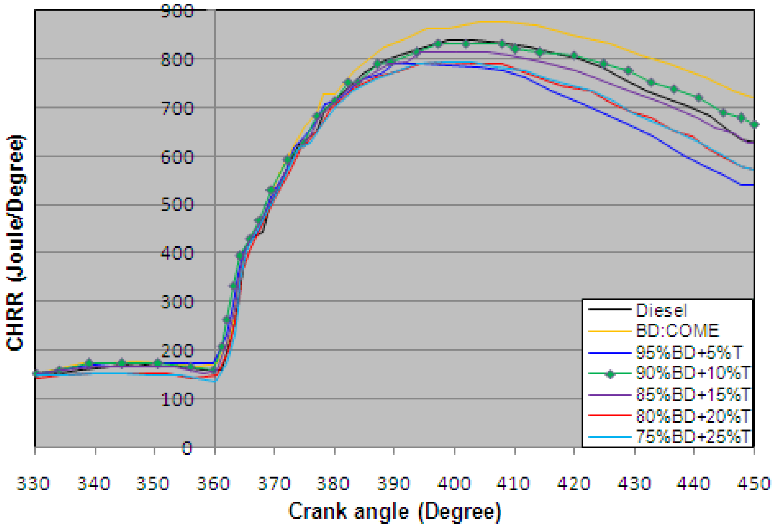

Fig. 9: Variation of cumulative heat release rate verses crank angle at full load

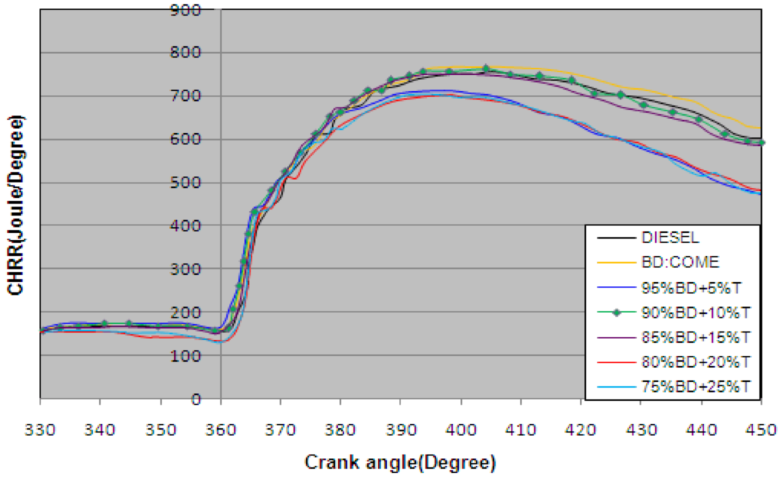

Fig. 10: Variation of cumulative heat release rate verses crank angle at 75% full load

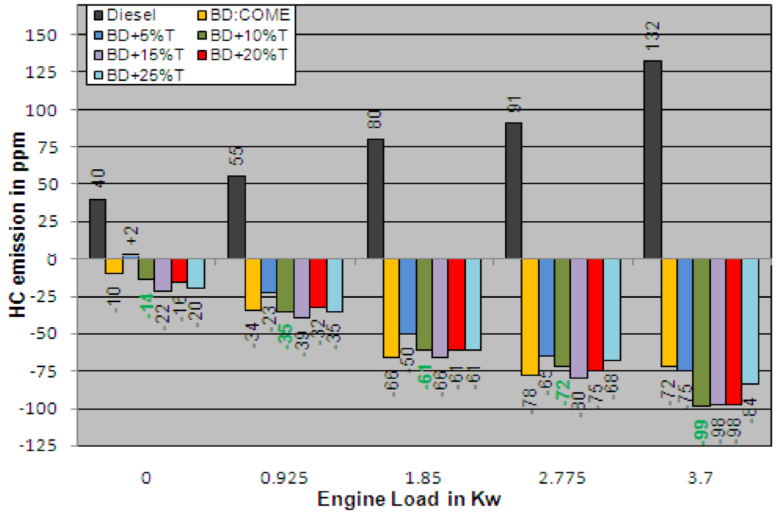

Fig. 11: Variation of Hydro carbon emission verses load on the engine

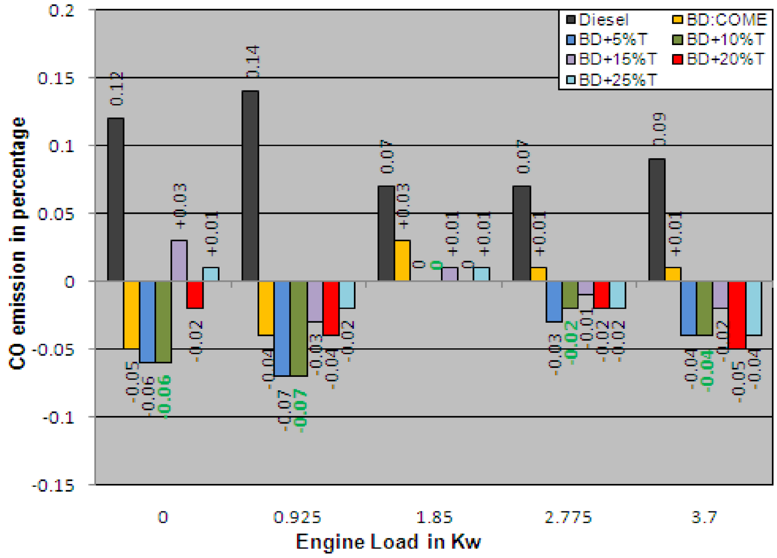

Fig. 12: Variation of carbon monoxide emission verses load on the engine

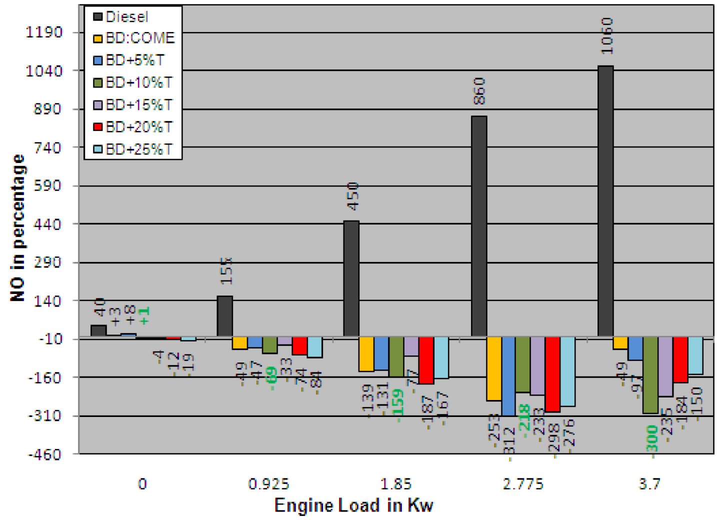

Fig. 13: Variation of NO emission verses load on the engine

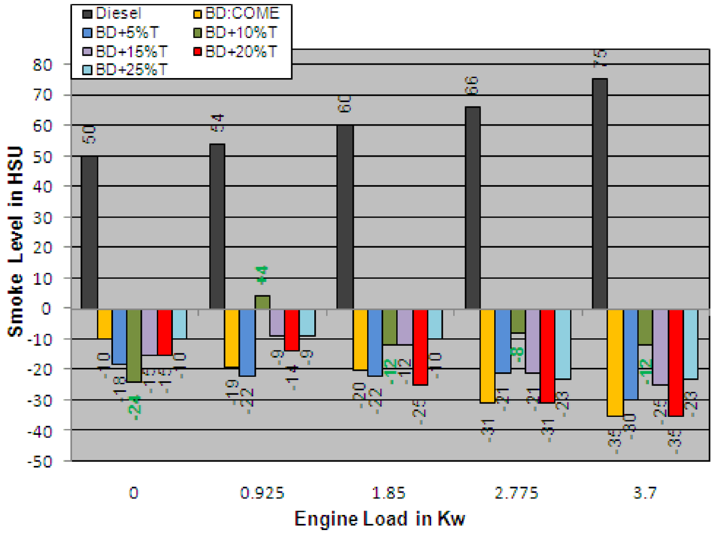

Fig. 14: Variation of smoke level verses load on the engine

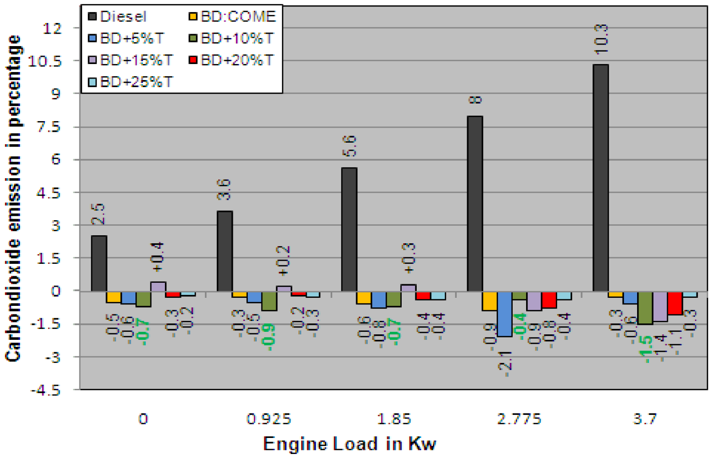

Fig. 15: Variation of carbon dioxide emission verses load on the engine

diesel fuel emissions. There is significant reduction in the HC emission in case of 10% blend of triacetin as observed in the Figure 11. This emission decreasing trend increased with the load on the engine. In Figure 12, one can observe better decreasing trend in the case of CO emission at partial loads and any how, trend continued in the full load operation of the engine. NO emission has also decreased (Figure 13) with respect to the increase of load on the engine. There is a smart decrease of NO at full load operation for 10% blend of Triacetin i.e. 1060-300=760ppm. One can infer that there is no trade off between the HC emission and NO emission with this application. Smoke levels (Figure 14) have obviously fallen with the triacetin blend in the context of the oxygen availability. Interestingly, the carbon dioxide levels have come down when compared to petro-diesel operation, because of lower carbon levels in the triacetin molecules comparatively as shown in Figure 15. With the results sorted out, 10% Triacetin blend with biodiesel yielded better results than the conventional diesel and biodiesel especially in the aspect of tail pie emissions.

CONCLUSION

The main experimental results are summarized as follows:

1 The triacetin's solubility with bio-diesel played important role in defining tail pipe emissions.
2 Biodiesel itself is touted as the vegetable ester that decreases the emission levels except NO. But there is significant NO emission decrease without sacrificing any emission level reduction when neat bio-diesel is used. There is uniform decrease in the emission levels with triacetin-biodiesel blends.

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