Original Research Article

EFFECT OF DI-TERT BUTYL PEROXIDE ON DIESEL ENGINE PERFORMANCE FUELLED BY BIODIESEL BLENDS

ABSTRACT

This study is motivated by the fact that the vegetable oils are being considered as the fuel of the future for the internal combustion engines, especially the compression ignition engines which are working with diesel as fuel. Different approaches for using the vegetable oils in CI engines as fuel are either to modify the oils to match with that of diesel to run successfully with these oils. Fuel additives are compounds formulated to enhance the quality and efficiency of the fuels used in motor vehicles. There are several benefits associated with the use of fuel additives.Di-tert butyl peroxide (DTBP) is effective forenhance the quality and efficiency of the fuels used in CI engine. The investigation was to check the feasibilityof di-tert butyl peroxide as an additive in different blends of diesel and jetrophabio-diesel on engine performance. The short-term tests on an unmodified diesel engine were conducted using the bio diesel and di-tert butyl peroxide blends (0, 10, 20, 30, 40, 50, and 100 per cent and 0, 0.5, 1.0, 1.5, 2.0, 2.5 per cent) with diesel. The engine performance and emission characteristics were measured during the short-term test.In all types of fuel, with increased percentage of load, brake specific energy consumption (BSEC) of the engine was observed to be decreased, on the other hand brake thermal efficiency, fuel consumption rate, sound level (db.), exhaust temperature, and the engine exhaust emissions like CO_2, CO, HC and NO_x was increased, respectively.

Keywords:*Bio diesel, Transesterification, CI engine, Di-tert butyl peroxide*

1. INTRODUCTION

Fuel and energy crisis and the concern of the society for the depleting world's non-renewable energy resources led to a renewed interest in the quest for alternative fuels.The increased industrialization and motorization of the world in recent years has resulted in great demand for petroleum products. Petroleum is the largest single source of energy, which has been consuming by the world's population, exceeding the other energy resources such as natural gas, coal, nuclear and renewable.The main consumers of energy are the electricity generation and transportation sectors. The diesel engine forms a vital part of both of these sectors throughout the world. Diesel fuel has versatile applications because of its high fuel efficiency compared to gasoline. Fuel crisis and environmental concerns have renewed interest of scientific community to look for alternative fuels of bio-origin such as vegetable oil. Bio-diesel was found as the best alternate fuel, technically and environmentally acceptable as well as easily available. Biodiesel consists of methyl/ethyl esters of fatty acids and is suitable for use in diesel engines(Mahesh *et al.*,2010).

General findings of almost all researchers are that CO, HC, SO_x and particulate matters of engine emissions decreased with increasing proportion of bio-diesel in diesel-biodiesel mixture with some increase in emission of NO_x. Presence of oxygen in bio-diesel is reported to be the reason for more complete combustion of carbon and hydrocarbon, while low sulfur content of biodiesel was responsible for reduction of SO_x(Behcet, 2011).

Rao et al. (2012) investigated a single cylinder direct injection diesel engine using diesel-biodiesel blends with cetane improver Ethyl Hexyl Nitrate (EHN) as an additive under different Exhaust Gas Recirculation (EGR) conditions. The combined effect of EGR and Ethyl Hexyl Nitrate on Exhaust emissions was studied. With increased in EGR percentage CO2, CO emissions increases while HC, NOX emissions decreases. Velmurugan and Gowthamn (2012). Tested a single cylinder direct injection diesel engine. Cetane improver additive of neopentaneis used with the varying proportions of 1, 3 and 5ml to the diesel fuel respectively. Addition of cetane improver additive to the diesel fuel is cost effective way to control NOx emission. Diesel fuel with the 3ml additive of neopentane shows the significant reduction in NOx and smoke .The sensitivity of NOX to change in cetane number is higher at low load than at high load. It is found that NOX emissions were reduced at low load than at high load. Ferreira et al. (2013) tested a single cylinder diesel generator with blends of diesel, biodiesel and ethanol at 1800 rpm that powered a resistive electric panel for mechanical performance and emissions profile of a diesel engine. Four different fuels were tested: B5 (95% diesel, 5% biodiesel v/v), B50 (50% diesel, 50% biodiesel v/v), 92% B50+8% E (46% diesel, 46% biodiesel, 8% ethanol v/v). Other composition was tested with the use of a cetane improver (DTBP: di-tert butyl peroxide) in a ratio of 0.5% (91.54%B50+7.96%E+0.5%A). The compositions were prepared using the S-10 diesel oil and soybean biodiesel. The Tests occurred at low load conditions. Emissions profile, specific fuel consumption and energy analysis were evaluated. It was noticed a decreasing in energy efficiency, NOx and CO emissions with increase in ethanol content and increasing of NOx emissions with Biodiesel addition. The use of DTBP showed a slight increase in energy efficiency, but an increasing in NOx and CO emissions was noticed. Venkateswarlu et al. (2013) studied and tested a single cylinder four stroke naturally aspirated direct injection air cooled diesel engine with exhaust gas recirculation and cetane improver Di Tertiary Butyl Peroxide (DTBP) as an additive to diesel-biodiesel blends. The combined effect of EGR and DTBP on Brake Thermal Efficiency(BTE), Brake Specific Fuel Consumption (BSFC), cylinder pressure and exhaust emissions is studied. Based on the experimental results it is found that an EGR percentage of around 15% results in maximum BTE and minimum BSFC. It is also found that the combined effect of EGR and cetane improver reduces the NOx emissions by 25% with a slight increase in Carbon Monoxide (CO), Hydro Carbon (HC) and smoke opacity. Patel and Singh (2014) studied and conducted on single cylinder four stroke diesel engines using blended soya methyl ester (B50) to optimize the NOx emission with the addition of DTBP cetane improver. The engine was first run on petroleum diesel (B0), followed by B50 and combination of B50 and DTBP. A number of combinations, 50% biodiesel (B50) and 50% petroleum diesel along with di-tert butyl peroxide (DTBP) such as B50/D0.5, B50/D1.0, B50/D1.5, B50/D2.0, B50/D2.5 and B50/D3, were used in this study. For each test, engine performance and emission were measured. The addition of cetane improver could reduce the NOx emission significantly with the penalty of Brake Specific Fuel Consumption (BSFC), CO and unburned hydrocarbon. The addition of DTBP by volumes of 0.5, 1, 1.5, 2, 2.5 and 3% to B50, the NOx reduction was found as 3.57, 5.0, 5.0, 4.29, 4.88 and 4.9%, respectively as compared to B50 without additive. It was also noted that CO and SOx reduce up to 25% and 33.33%, respectively, compared with petroleum diesel when 1% of DTBP is used. Considering the emission parameters, and the cost of the additive, 1% DTBP would give the optimum results for NOx reduction. Krishnamoorthi and Natarajan (2015) studied and evaluated the effects of diethyl ether as additive with waste fried oil/diesel blend on the performance and emissions of a direct injection diesel engine. The waste fried oil and diesel blending with diethyl ether (DEE) in the ratio of 0:100:0, 20:80:0, 30:70:0, 40:60:0, 15:80:5, 25:70:5 and 35:60:5 by volume were tested in CI Engine. The results show that compared with neat diesel, there is slightly lower brake specific fuel consumption (BSFC) for diesel waste fried oil and DEE blend. Strong reduction in emission is observed with diesel-bio waste fried oil and DEE at various engine loads. Waste fried oil at 25% and DEE 5% blend with diesel gave best performance in terms of low smoke intensity, emissions of HC, CO, CO_2 and NOx. Vadivela et al. (2015) conducted and studied the effects of using diethyl ether as an additive to biodiesel/diesel blend on the performance and emission of a direct injection diesel engine. The mahua/mustard biodiesel and diesel are blended with diethyl ether (DEE) in the ratio of 0:100:0, 20:80:0, 30:70:0, 40:60:0, 15:80:5, 25:70:5 and 35:60:5 by volume and tested in CI Engine. The results obtained were compared with neat diesel, there was slightly lower brake specific fuel consumption for diesel, biodiesel and DEE blend. Strong reduction in emissions was observed with diesel, biodiesel and DEE at various engine loads.

Methyl ester of mustard biodiesel at 25% and DEE 5% blend with 70% diesel gave best performance in terms of low smoke intensity and emissions characteristics. Raj and Karthikayan (2016) investigated and studied the effect of Di-tert butyl peroxide (DTBP) as additive on the performance, exhaust emissions and combustion characteristics of a single cylinder direct injection compression ignition engine fuelled with papaya seed oil methyl ester (PSME). Base data was generated on a 5.2 kW single-cylinder diesel engine with standard diesel fuel. PSME-diesel blends ranging from 25 to 100% of PSME with diesel fuel by volume were prepared and tested in the diesel engine without and with the addition of DTBP. Improved performance reduced NOx emissions with slight increase in smoke density and HC emissions were observed for PSME blends with additive than those for PSME blends without additive. Earlier heat release and increase in cylinder pressure were also observed for blends with additive.

2. MATERIALS AND METHODS

2.1 Production of bio-diesel

Fresh oil was extracted from *Jatropha Curcas* seed using a mini oil expeller. Bio-diesel of *Jatropha Curcas* oil was prepared as per the procedure recommended by Gupta, 1984. Various steps involved in this procedure are shown in Fig. 1. Moisture free methanol was used in the methanol oil molar ratio of 6:1 (for 100 ml oil, 20 ml methanol and sodium hydroxide (1% by weight of oil) was used as catalyst. A homogenous moisture of methanol and sodium hydroxide was made.

The method basically involved five steps:

i. Heating of oil 60ºC (oil temperature kept below the boiling point of methanol i.e. 65ºC).
ii. Mixing of heated oil and alkaline methanol. The mixing was done in a stainless steel container, as stainless steel is inert to the corrosive action of sodium hydroxide and to the action of organic solvent methanol.
iii. Separation of glycerol (which settles at the bottom) and fatty acid methyl esters.
iv. Decanting of prepared ester and its washings with water (3-4 times) to remove any impurities left. Separation of ester from water by 2nd decantation.
v. Heating of decanted ester to remove all the traces of moisture.

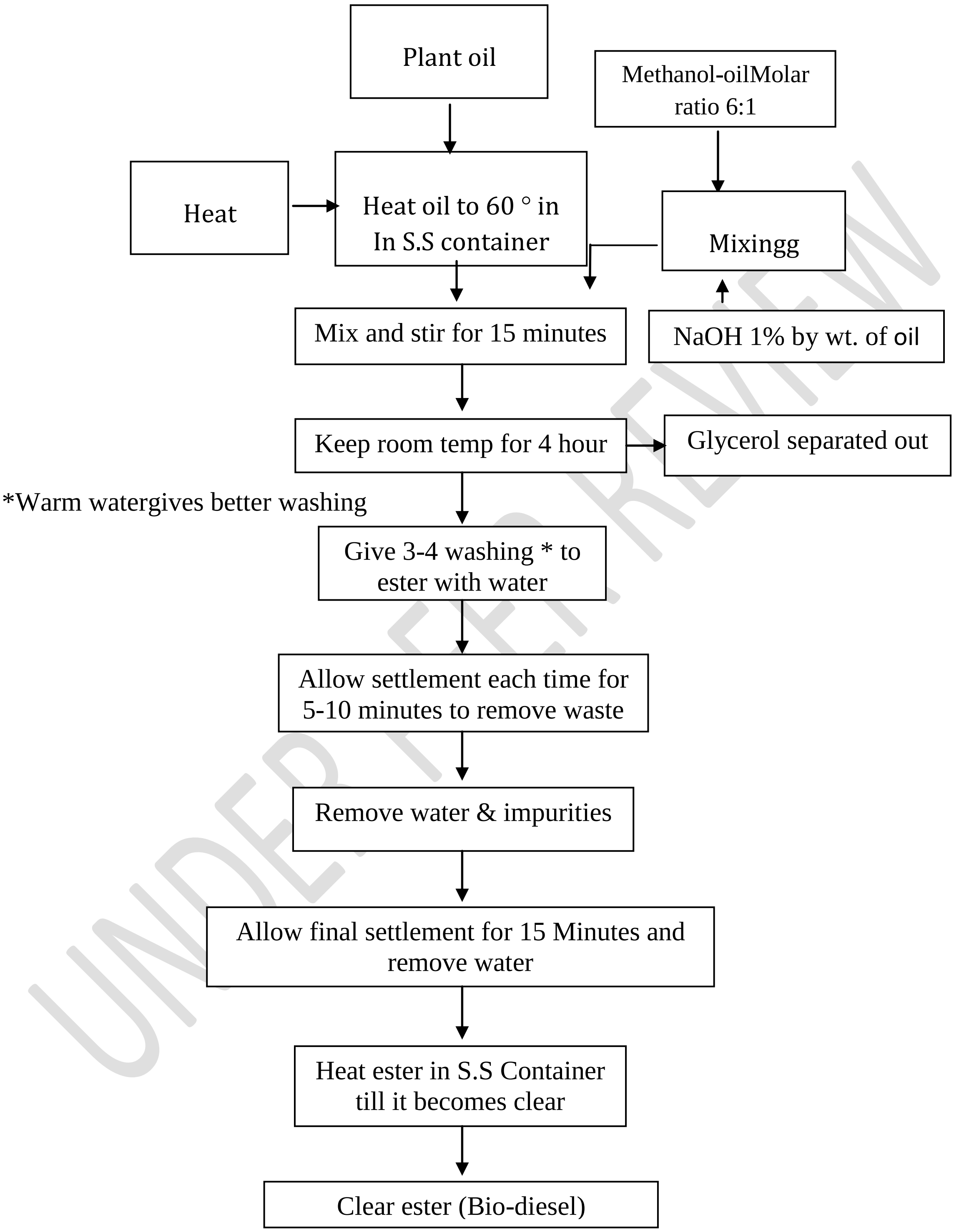

Chart 1. Simplified procedure for batch level esterification of plant oils

2.2 Fuel characterization of bio-diesel and its blends

Characterization of diesel and biodiesel was done at Department of Renewable Energy Engineering, Anand Agricultural University, Godhra, as per the ASTM standards (ASTM-1983). The following characteristics were determined for the said fuel.

1. Kinematic viscosity
2. Density
3. Flash and fire point
4. Cloud and pour point
5. Calorific value

Methods used for determination of different characteristics of fuels are as per standard.

2.3 Experimental set- up

An experimental setup was prepared in the Biofuel laboratory of Department of Renewable Energy Engineering, CAET, AAU, Godhra. The set up was comprising of one single cylinder engine with 5 kW load resistance for powermeasurement device, exhaust gas temperature sensors fitted at exhaust of the engine, sound level meter and digital microprocessor based exhaust gas analyzer and NO_x analyzer.A Swati make (TV1/SV1), single cylinder, four stroke, water-cooled diesel engine having 16.5:1 compression ratio was selected for the study.CO and HC

Blends were prepared by mixing Jatropha methyl ester with diesel in proportion of 10,20,30,40,50 and 100 percent on volume basis. The proportion of blend was identified by B10, B20, B30, B40, B50 and B100 where they stand for 10,20,30,40,50 and 100 percent ester with 90,80,70,60,50 and 0 percent diesel on volume basis respectively and were finally designated as B10, B20, B30, B40, B50, B100 and D100. In all, the fuels under test were seven in number along with diesel as control designated as D100.

The equipped sub systems in the engine set up were:

i) Engine coupled to a generating set.
ii) Fuel supply and measuring unit.
iii) Electrical loading device.
iv) Power measuring unit.

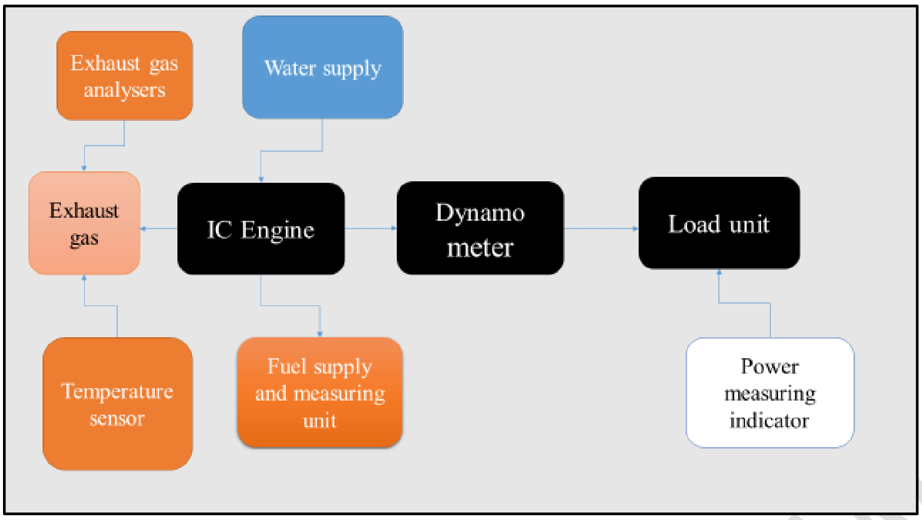

Chart 2. Schematic diagram of experimental set up

2.4 Exhaust gas analyzers

Three types of exhaust gas analyser is used for measuring concentration of different exhaust gas components.

1) Gas board analyser
2) NO_x gas analyser
3) ECO GAS 100 gas analyser

Pic 1. Gas board analyser

Pic 2. NOx gas analyser

Pic 3. ECO GAS 100 gas analyser

2.5Engine power performance

a) Power developed by engine

Power in kW = (V x I)/1000

where,

V = Voltage (Volt)

I= Current (Ampere)

b) Break specific fuel consumption (BSFC)

Total Fuel Consumption TFC

$$TFC = (v \times \tau \times 3600)/t$$

Where,

TFC = Total fuel consumption, g/h

v =Volume of fuel, ml

τ = Specific gravity of the fuel,

t =Time taken to consume specific volume of fuel, sec

c) Brake specific energy consumption (BSEC)

Break specific fuel consumption=Total fuel consumption / Power output,

BSFC = (TFC/P)(kg/kWh)

d) Brake thermal efficiency (BTE)

$$\eta_{bt}\,(\%) = \frac{\text{Energy equivalent of brake power (Kw)}}{\text{Energy supplied by fuel (Kw)}} \times 100$$

Dharmadhikari (2012)

3. RESULTS AND DISSCUSION

This is the analysis and representation of the experimental data collected during the course investigation.

The short duration engine performance test was conducted using diesel (100%) fuel for comparison with blends of biodiesel with diesel (10, 20, 30, 40, 50 and 100%) with different proportion of di-tert butyl peroxide (DTBP) (0.5, 1.0, 1.5, 2.0 and 2.5%) at various engine load conditions (0, 20, 40, 60, 80 and 100 %).

3.1 Performance of CI engine with different loads, different blends of biodiesel with diesel fuel and different proportions of DTBP additive.

i. Brake specific fuel consumption

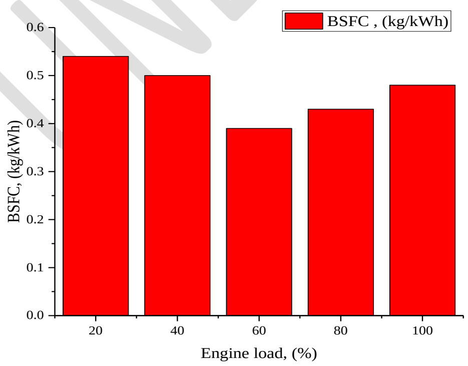

Fig.1Variation in brake specific fuel consumption of engine with different engine loads using 100 % diesel

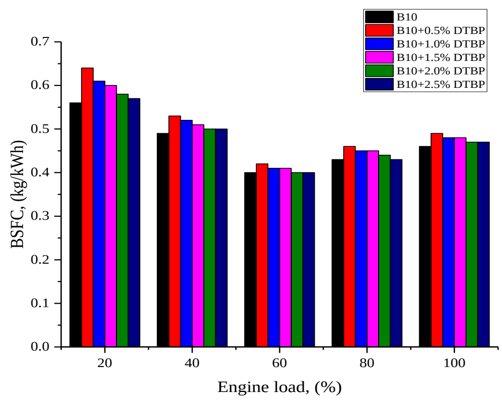

Fig.2Variation in brake specific fuel consumption of engine with different engine loads using B10 with different proportion of

DTBP

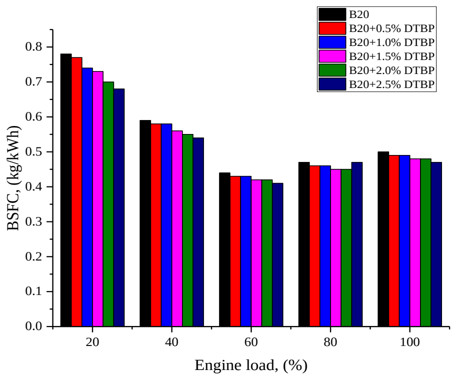

Fig.3Variation in brake specific fuel consumption of engine with different engine loads using B20 with different proportion of DTBP

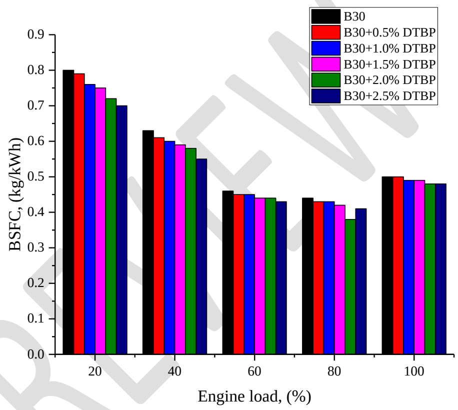

Fig.4Variation in brake specific fuel consumption of engine with different engine loads using B30 with different proportion of DTBP

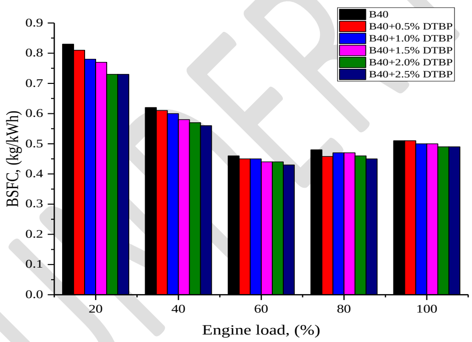

Fig.5Variation in brake specific fuel consumption of engine with different engine loads using B40 with different proportion of DTBP

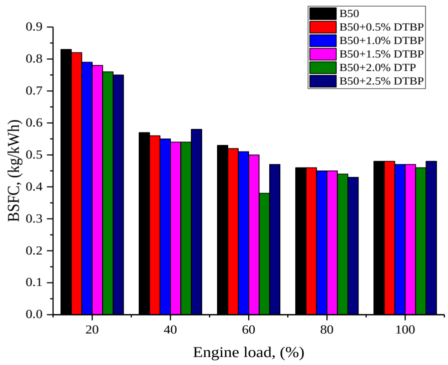

Fig.6Variation in brake specific fuel consumption of engine with different engine loads using B50 with different proportion of DTBP

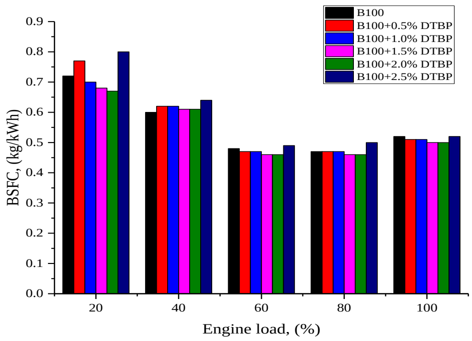

Fig.7Variation in brake specific fuel consumption of engine with different engine loads using B100 with different proportion of DTBP

Brake specific fuel consumption designated as BSFC is the quantity of fuel consumed per kilowatt per hour in an engine. Brake specific fuel consumption of CI engine was measured with different combination of blends with diesel and different load conditions. It was also showed that all the independent parameters significantly affect the Brake specific fuel consumption of the CI engine.

The variation in brake specific fuel consumption at diesel fuel (100%), blends of biodiesel with diesel (10, 20, 30, 40, 50 and 100%) with different proportion of DTBP(0.5, 1.0, 1.5, 2.0 and 2.5%) at various load conditions (0, 20, 40, 60, 80 and 100 %) is shown in Fig. 1 to Fig. 7.The maximum and minimum in brake specific fuel consumption was observed 0.84 kg/kWh with $B_5A_1L_1$ and 0.37 kg/kWh with $B_3A_5L_5$ treatment combination respectively.

ii. Brake specific energy consumption

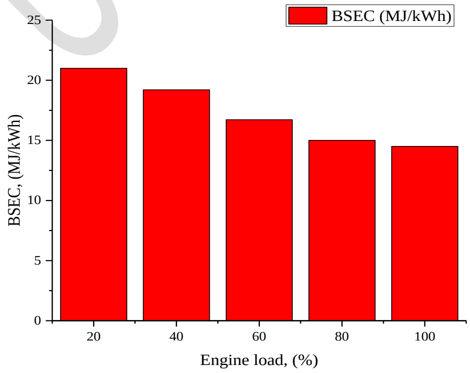

Fig. 8Variation in brake specific energy

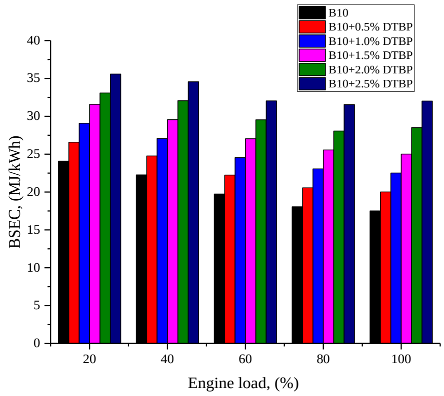

Fig. 9 Variation in brake specific energy

consumption of engine with different engine loads using 100 % diesel

consumption of engine with different engine loads using B10 with different proportion of DTBP

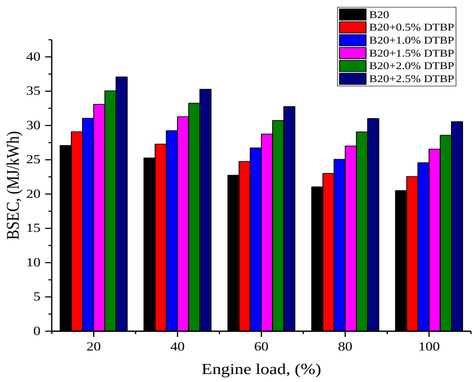

Fig. 10 Variation in brake specific energy consumption of engine with different engine loads using B20 with different proportion of DTBP

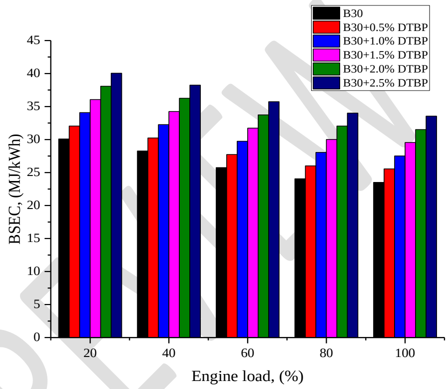

Fig. 11 Variation in brake specific energy consumption of engine with different engine loads using B30 with different proportion of DTBP

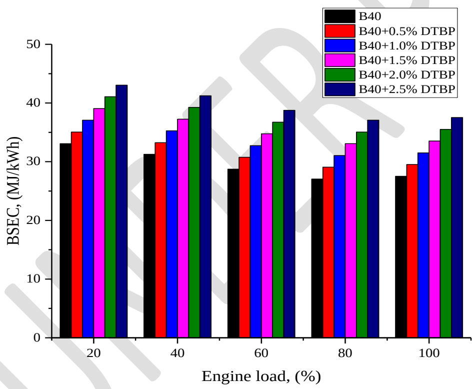

Fig. 12 Variation in brake specific energy consumption of engine with different engine loads using B40 with different proportion of DTBP

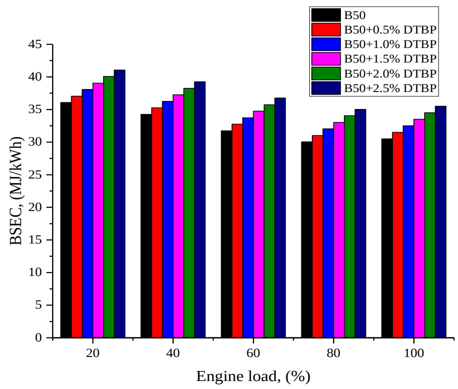

Fig. 13 Variation in brake specific energy consumption of engine with different engine loads using B50 with different proportion of DTBP

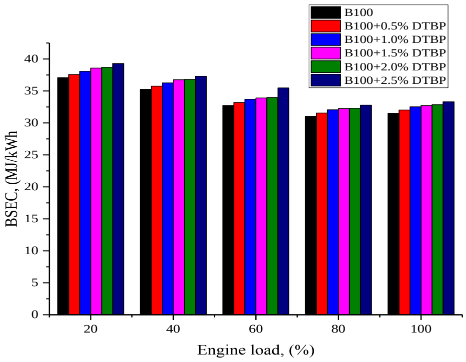

Fig. 14 Variation in brake specific energy consumption of engine with different engine loads using B100 with different proportion of DTBP

Brake specific energy consumption designated as BSFC is the quantity of energy consumed per kilowatt per hour in an engine. Brake specific energy consumption of CI engine was measured with different combination of blends with diesel and different load conditions. It was also showed that all the independent parameters significantly affect the Brake specific fuel consumption of the CI engine.

The variation in brake specific energy consumption at diesel fuel (100%), blends of biodiesel with diesel (10, 20, 30, 40, 50 and 100%) with different proportion of DTBP (0.5, 1.0, 1.5, 2.0 and 2.5%) at various load conditions (0, 20, 40, 60, 80 and 100 %) is shown in Fig. 8 to Fig. 14.The maximum and minimum in brake specific fuel consumption was observed 42.15MJ/kWhwith $B_4A_6L_2$ and 17.51MJ/kWh with $B_1A_1L_6$ treatment combination respectively.

iii. Brake power

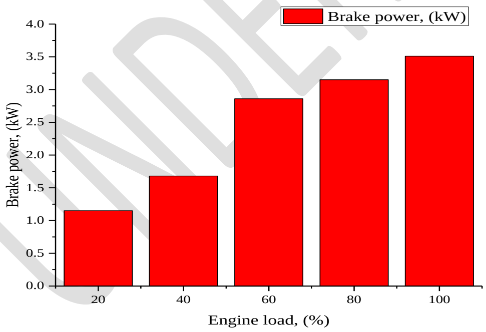

Fig. 15 Variation in brake power (kW) of engine with different engine loads using 100 % diesel

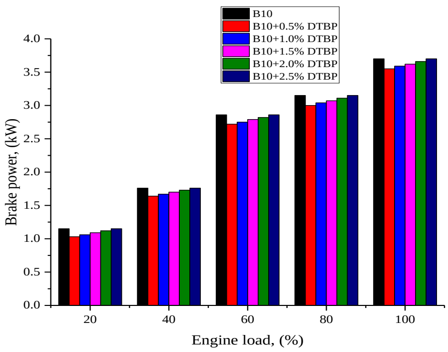

Fig. 16 Variation in brake power (kW) of engine with different engine loads using B10 with different proportion of DTBP

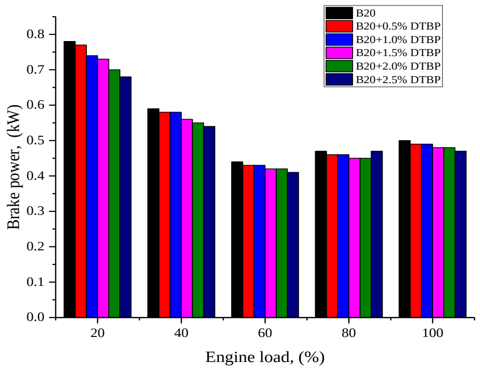

Fig. 17 Variation in brake power (kW) of engine with different engine loads using B20 with different proportion of DTBP

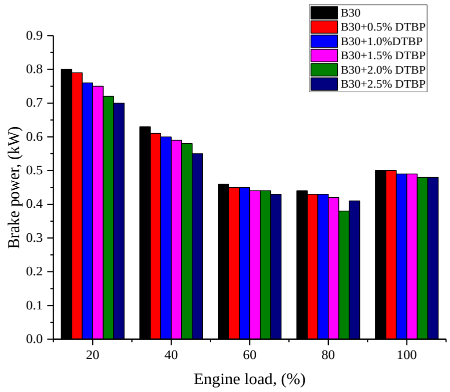

Fig. 18 Variation in brake power (kW) of engine with different engine loads using B30 with different proportion of DTBP

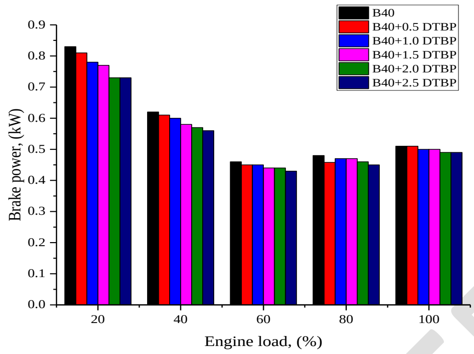

Fig. 19 Variation in brake power (kW) of engine with different engine loads using B40 with different proportion of DTBP

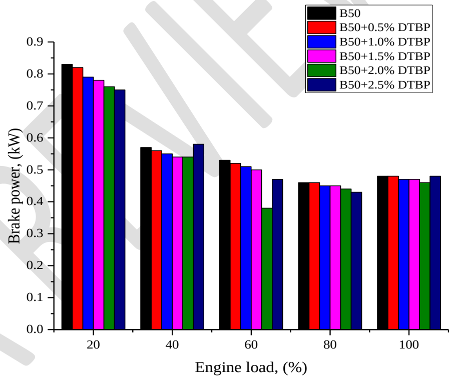

Fig. 20 Variation in brake power (kW) of engine with different engine loads using B50 with different proportion of DTBP

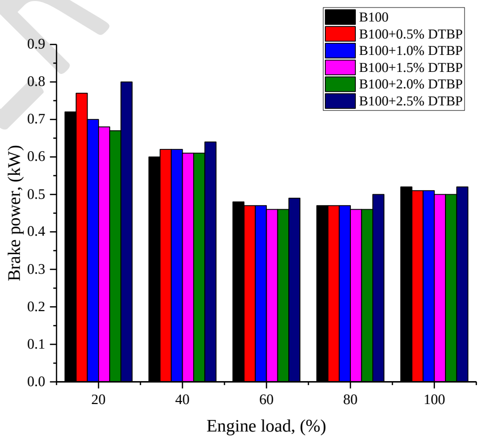

Fig. 21 Variation in brake power (kW) of engine with different engine loads using B100 with different proportion of DTBP

Brake power (kW) of CI engine was measured with different combination of blends with diesel and different load conditions. It was also showed that all the independent parameters significantly affect the Brake power of the CI engine.

The variation in brake power at diesel fuel (100%), blends of biodiesel with diesel (10, 20, 30, 40, 50 and 100%) with different proportion of DTBP (0.5, 1.0, 1.5, 2.0 and 2.5%) at various load conditions (0, 20, 40, 60, 80 and 100 %) is shown in Fig. 15 to Fig. 21.The maximum and minimum in brake power (kW) was observed 3.97kWwith $B_6A_5L_6$ and 0.85kW with $B_4A_1L_2$ treatment combination respectively.

iv. Brake thermal efficiency

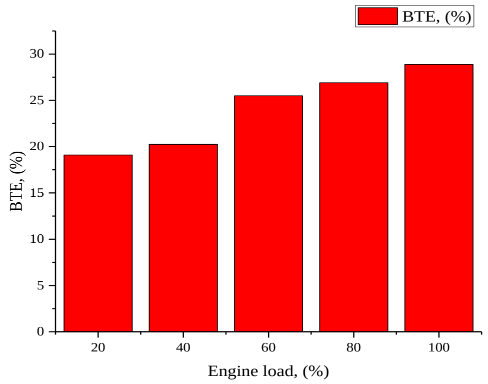

Fig. 22 Variation in brake thermal efficiency (%) of engine with different engine loads using 100 % diesel

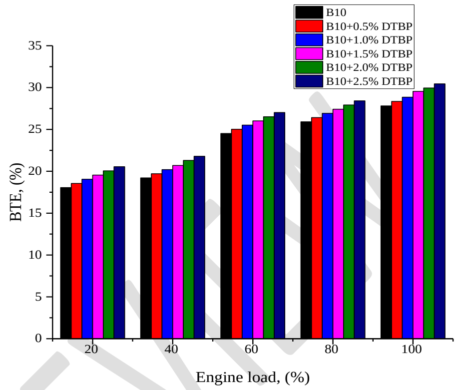

Fig. 23 Variation in brake thermal efficiency (%) of engine with different engine loads using B10 with different proportion of DTBP

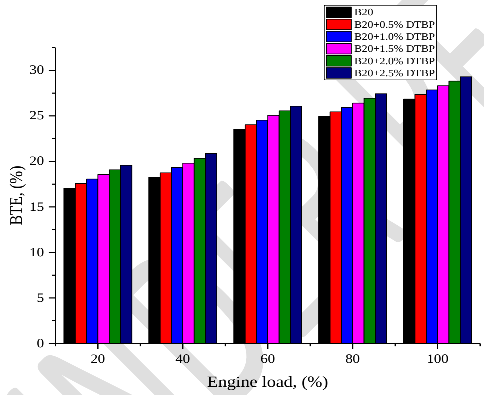

Fig. 24 Variation in brake thermal efficiency (%) of engine with different engine loads using B20 with different proportion of DTBP

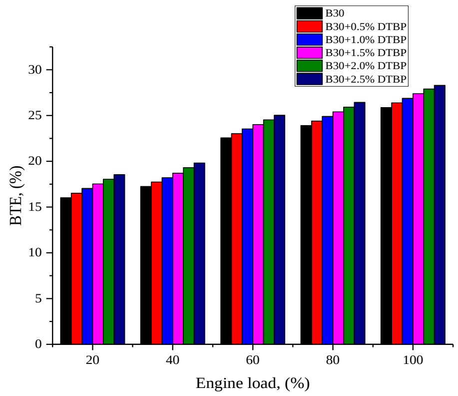

Fig. 25 Variation in brake thermal efficiency (%) of engine with different engine loads using B30 with different proportion of DTBP

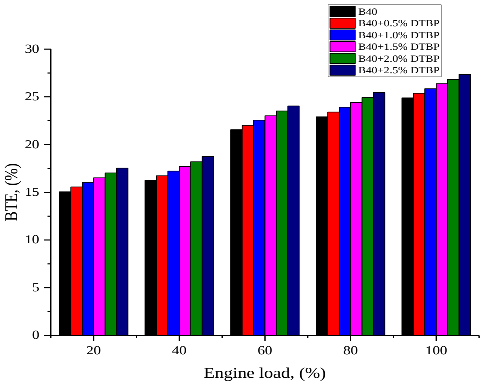

Fig. 26 Variation in brake thermal efficiency (%) of engine with different engine loads using B40 with different proportion of DTBP

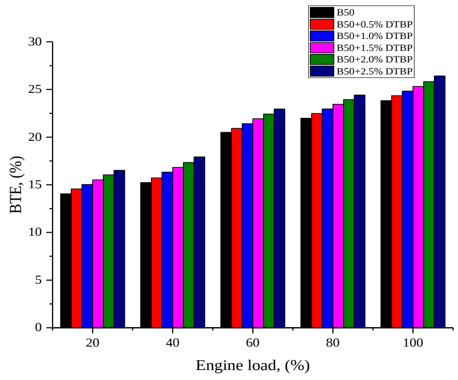

Fig. 27 Variation in brake thermal efficiency (%) of engine with different engine loads using B50 with different proportion of DTBP

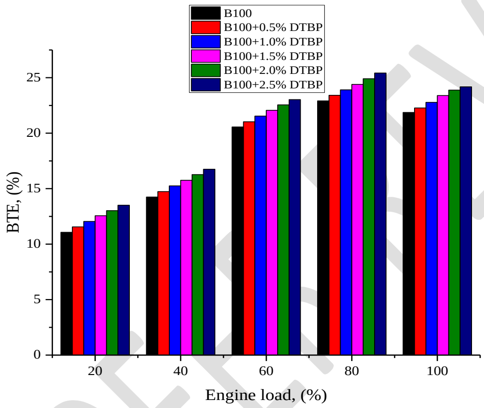

Fig. 28 Variation in brake thermal efficiency (%) of engine with different engine loads using B100 with different proportion of DTBP

Brake thermal efficiency (%) of CI engine was measured with different combination of blends with diesel and different load conditions. It was also showed that all the independent parameters significantly affect the Brake thermal efficiency (%) of the CI engine.

The variation in brake power at diesel fuel (100%), blends of biodiesel with diesel (10, 20, 30, 40, 50 and 100%) with different proportion of DTBP (0.5, 1.0, 1.5, 2.0 and 2.5%) at various load conditions (0, 20, 40, 60, 80 and 100 %) is shown in Fig. 22 to Fig. 28.The maximum and minimum in brake thermal efficiency (%) was observed 30.55 % with $B_1A_6L_6$ and 10.97 % with $B_{26}A_1L_2$ treatment combination respectively.

3.2 Emission characteristics CI engine with different loads, different blends of biodiesel with diesel fuel and different proportions of DTBP additive.

a) Carbon dioxide (CO_2)

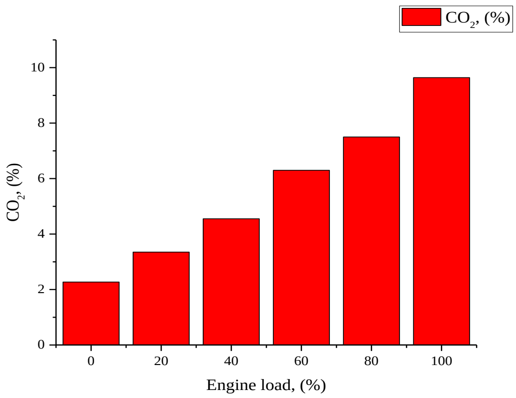

Fig. 29 Variation in carbon dioxide (CO2) (%) of engine with different engine loads using 100 % diesel

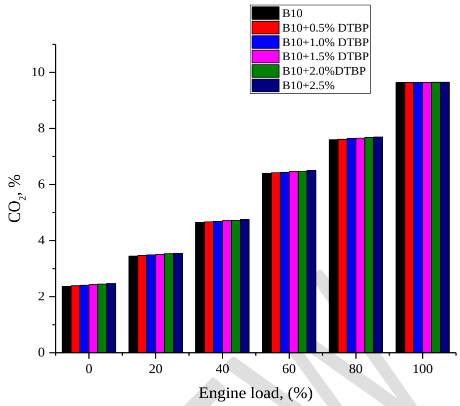

Fig. 30 Variation in carbon dioxide (CO2) (%) of engine with different engine loads using B10 with different proportion of DTBP

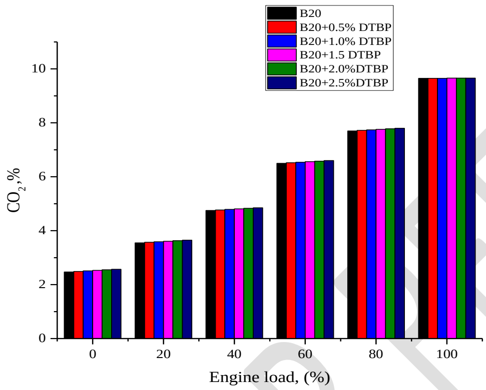

Fig. 31 Variation in carbon dioxide (CO2) (%) of engine with different engine loads using B20 with different proportion of DTBP

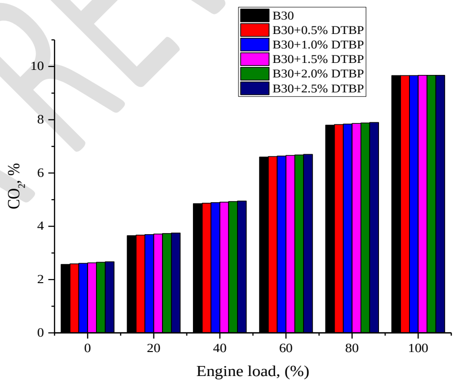

Fig. 32 Variation in carbon dioxide (CO2) (%) of engine with different engine loads using B30 with different proportion of DTBP

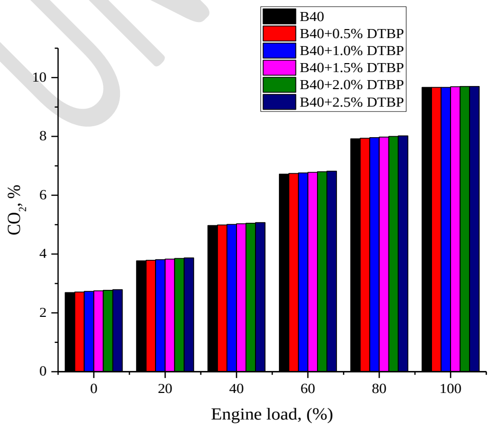

Fig. 33 Variation in carbon dioxide (CO2) (%) of engine with different engine loads using B40

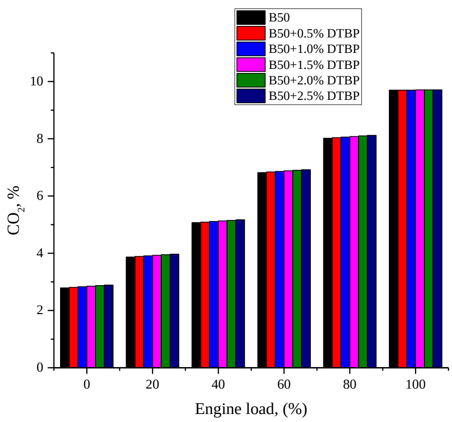

Fig. 34 Variation in carbon dioxide (CO2) (%) of engine with different engine loads

with different proportion of DTBP

using B50 with different proportion of DTBP

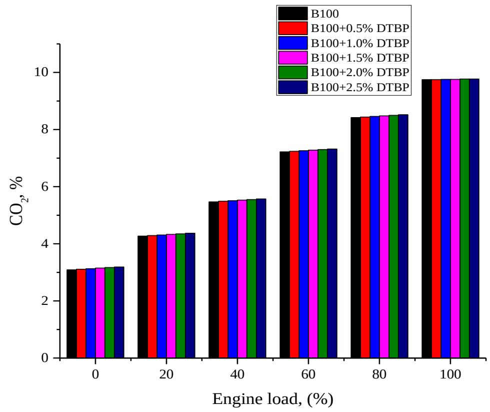

Fig. 35 Variation in carbon dioxide (CO2) (%) of engine with different engine loads using B100 with different proportion of DTBP

Carbon dioxide (CO_2) (%) of CI engine was measured with different combination of blends with diesel and different load conditions. It was also showed that all the independent parameters significantly affect the Carbon dioxide (CO_2) (%) of the CI engine.

The variation in Carbon dioxide (CO_2) at diesel fuel (100%), blends of biodiesel with diesel (10, 20, 30, 40, 50 and 100%) with different proportion of DTBP (0.5, 1.0, 1.5, 2.0 and 2.5%) at various load conditions (0, 20, 40, 60, 80 and 100 %) is shown in Fig. 29 to Fig. 35.The maximum and minimum in Carbon dioxide (CO_2) (%) was observed 9.8 % with $B_6A_6L_6$ and 2.2 % with $B_5A_6L_3$ treatment combination respectively.

b) Carbon monoxide (CO)

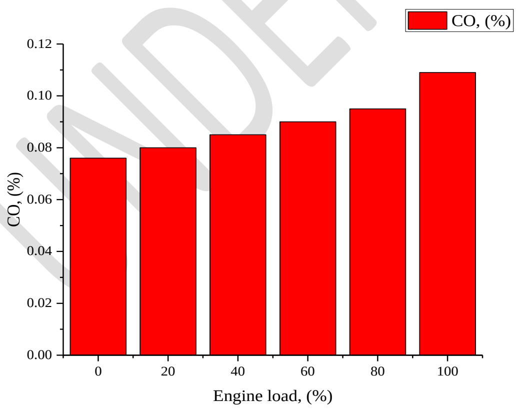

Fig. 36 Variation in carbon monoxide (CO) (%) emission of engine with different engine loads using 100 % diesel

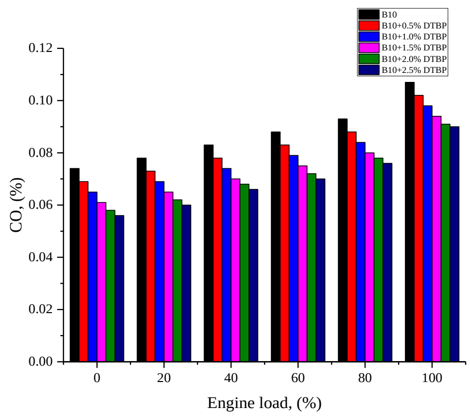

Fig. 37 Variation in carbon monoxide (CO) (%) emission of engine with different engine loads using B10 with different proportion of DTBP

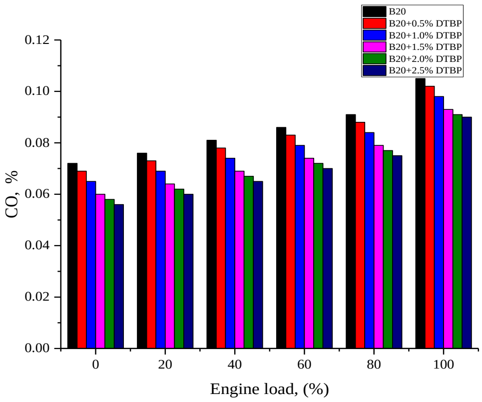

Fig. 38 Variation in carbon monoxide (CO) (%) emission of engine with different engine loads using B20 with different proportion of DTBP

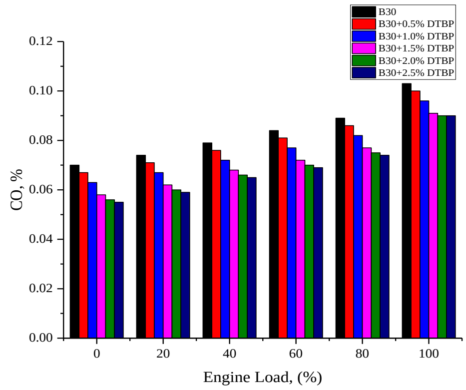

Fig. 39 Variation in carbon monoxide (CO) (%) emission of engine with different engine loads using B30 with different proportion of DTBP

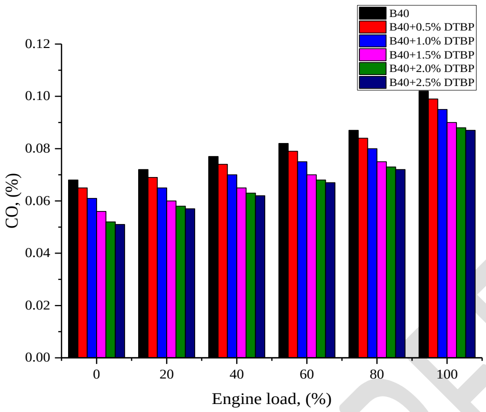

Fig. 40 Variation in carbon monoxide (CO) (%) emission of engine with different engine loads using B40 with different proportion of DTBP

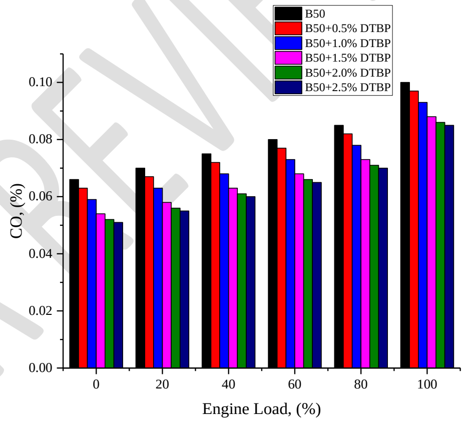

Fig. 41 Variation in carbon monoxide (CO) (%) emission of engine with different engine loads using B50 with different proportion of DTBP

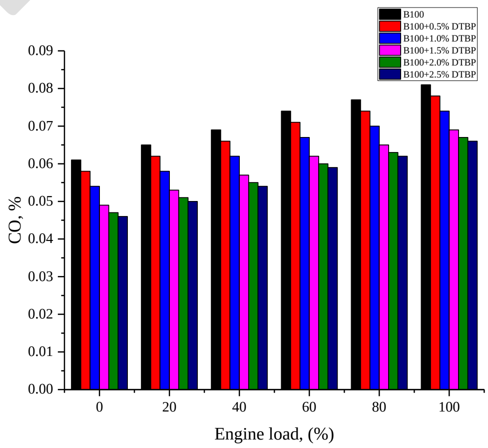

Fig. 42 Variation in carbon monoxide (CO) (%) emission of engine with different engine loads using B100 with different proportion of DTBP

Carbon monoxide (CO) (%) of CI engine was measured with different combination of blends with diesel and different load conditions. It was also showed that all the independent parameters significantly affect the Carbon dioxide (CO_2) (%) of the CI engine.

The variation in carbon monoxide (CO) (%) at diesel fuel (100%), blends of biodiesel with diesel (10, 20, 30, 40, 50 and 100%) with different proportion of DTBP (0.5, 1.0, 1.5, 2.0 and 2.5%) at various load conditions (0, 20, 40, 60, 80 and 100 %) is shown in Fig. 36 to Fig. 42.The maximum and minimum in carbon monoxide (CO) (%) was observed 0.107 % with $B_1A_1L_6$ and 0.046 % with $B_6A_6L_1$ treatment combination respectively. Carbon monoxide (CO) emission permissible limit is 0.0687 %.

c) Nitrogen oxides (NO_X)

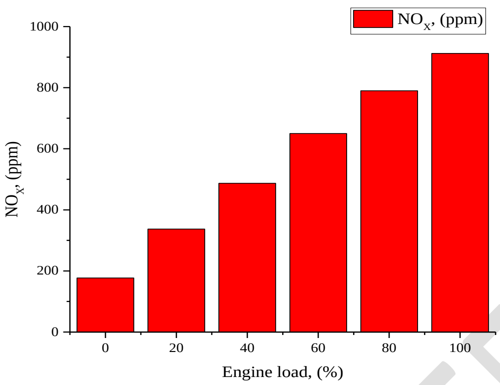

Fig. 43 Variation in nitrogen oxides (NOX) (ppm) emission of engine with different engine loads using 100 % diesel.

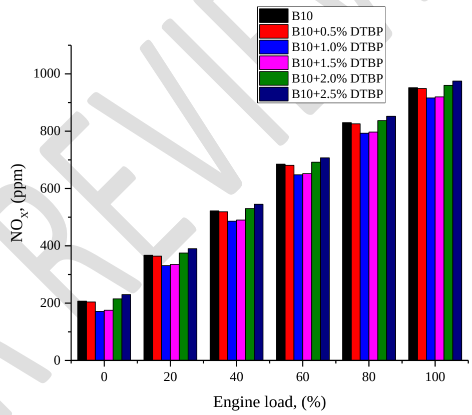

Fig. 44 Variation in nitrogen oxides (NOX) (ppm) emission of engine with different engine loads using B10 with different proportion of DTBP

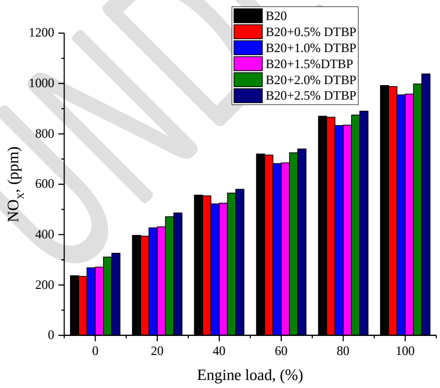

Fig. 45 Variation in nitrogen oxides (NOX) (ppm) emission of engine with different engine loads using B20 with different proportion of DTBP

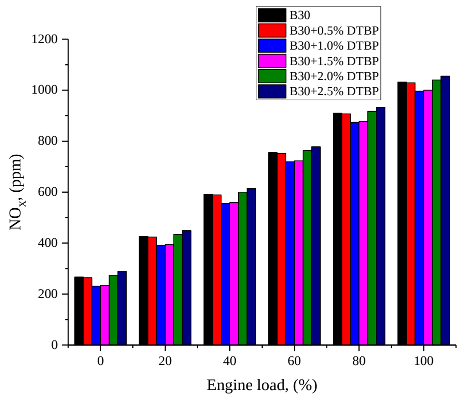

Fig. 46 Variation in nitrogen oxides (NOX) (ppm) emission of engine with different engine loads using B30 with different proportion of DTBP

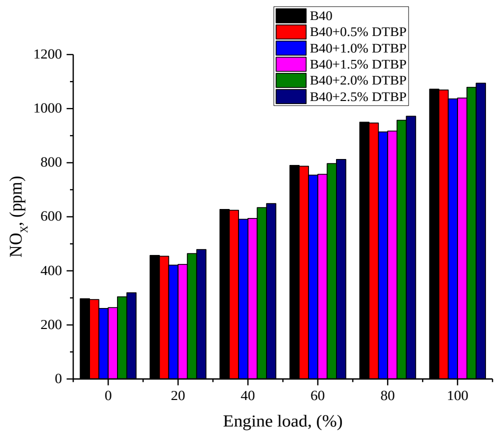

Fig. 47 Variation in nitrogen oxides (NOX) (ppm) emission of engine with different engine loads using B40 with different proportion of DTBP

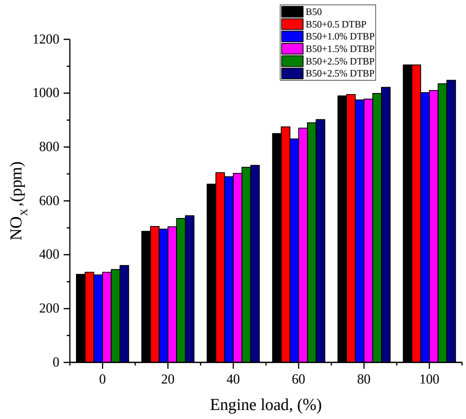

Fig. 48 Variation in nitrogen oxides (NOX) (ppm) emission of engine with different engine loads using B50 with different proportion of DTBP

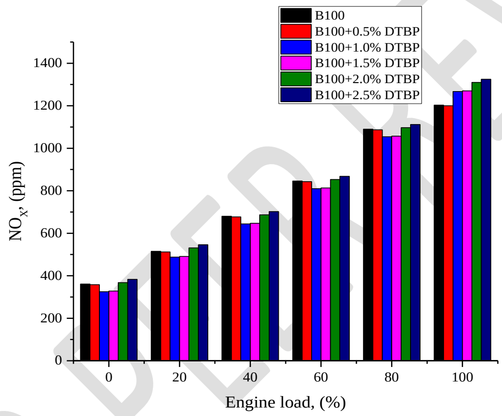

Fig. 49 Variation in nitrogen oxides (NOX) (ppm) emission of engine with different engine loads using B100 with different proportion of DTBP

Nitrogen oxides (NO_X) (ppm)of CI engine was measured with different combination of blends with diesel and different load conditions. It was also showed that all the independent parameters significantly affect the nitrogen oxides (NO_X) (ppm)of the CI engine.

The variation in nitrogen oxides (NO_X) (ppm)at diesel fuel (100%), blends of biodiesel with diesel (10, 20, 30, 40, 50 and 100%) with different proportion of DTBP (0.5, 1.0, 1.5, 2.0 and 2.5%) at various load conditions (0, 20, 40, 60, 80 and 100 %) is shown in Fig. 43 to Fig. 49.The maximum and minimum in nitrogen oxides (NO_X) (ppm)was observed 1325 ppm with $B_6A_6L_6$ and 171 ppm with $B_1A_3L_1$ treatment combination respectively. Nitrogen oxides (NO_x) permissible limit is 1011 ppm.

d) Hydrocarbons (HC)

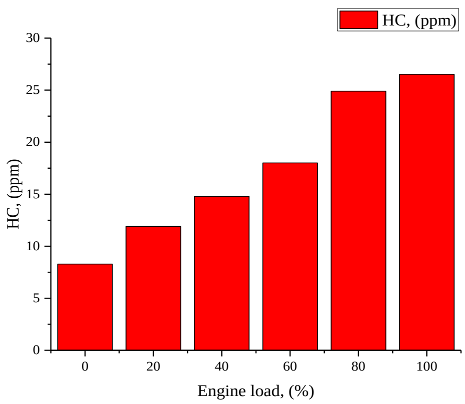

Fig. 50 Variation in hydrocarbons (HC) (ppm) emission of engine with different engine loads using 100% diesel

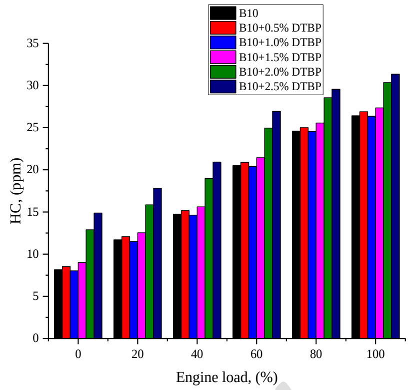

Fig. 51 Variation in hydrocarbons (HC) (ppm) emission of engine with different engine loads using B10 with different proportion of DTBP

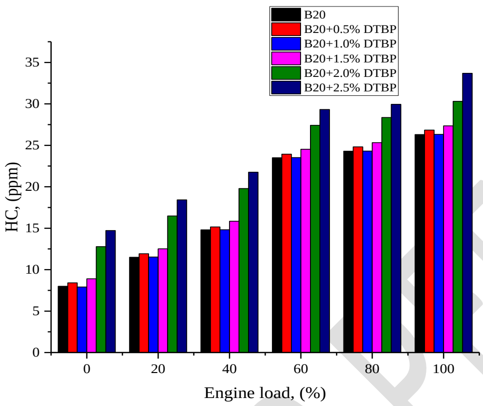

Fig. 52 Variation in hydrocarbons (HC) (ppm) emission of engine with different engine loads using B20 with different proportion of DTBP

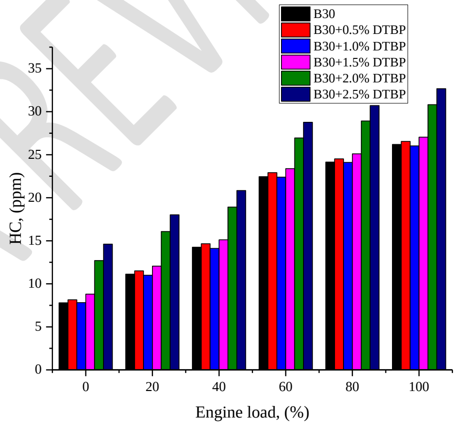

Fig. 53 Variation in hydrocarbons (HC) (ppm) emission of engine with different engine loads using B30 with different proportion of DTBP

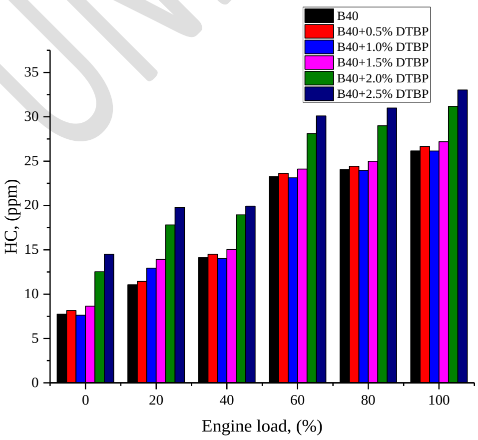

Fig. 54 Variation in hydrocarbons (HC) (ppm) emission of engine with different engine loads

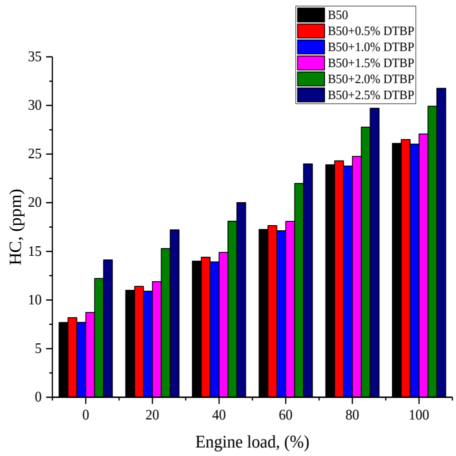

Fig. 55. Variation in hydrocarbons (HC) (ppm) emission of engine with different

using B40 with different proportion of DTBP

engine loads using B50 with different proportion of DTBP

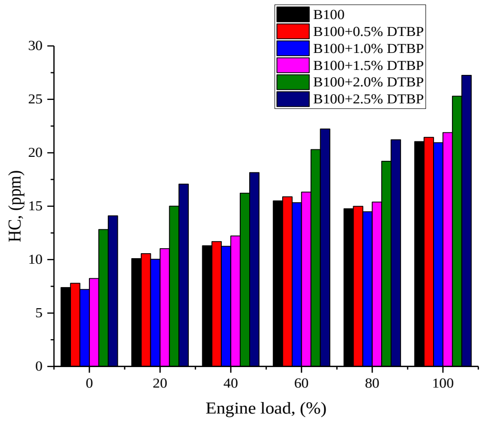

Fig. 56 Variation in hydrocarbons (HC) (ppm) emission of engine with different engine loads using B100 with different proportion of DTBP

Hydrocarbons (HC) (ppm)of CI engine was measured with different combination of blends with diesel and different load conditions. It was also showed that all the independent parameters significantly affect the hydrocarbons (HC) (ppm)of the CI engine.

The variation in hydrocarbons (HC) (ppm)at diesel fuel (100%), blends of biodiesel with diesel (10, 20, 30, 40, 50 and 100%) with different proportion of DTBP (0.5, 1.0, 1.5, 2.0 and 2.5%) at various load conditions (0, 20, 40, 60, 80 and 100 %) is shown in Fig. 50 to Fig. 56.The maximum and minimum in hydrocarbons (HC) (ppm)was observed 33.69 ppm with $B_2A_6L_6$ and 7.21 ppm with $B_6A_3L_1$ treatment combination respectively. Hydrocarbons (HC) permissible limit is 480 ppm.

e) Exhaust gas temperature

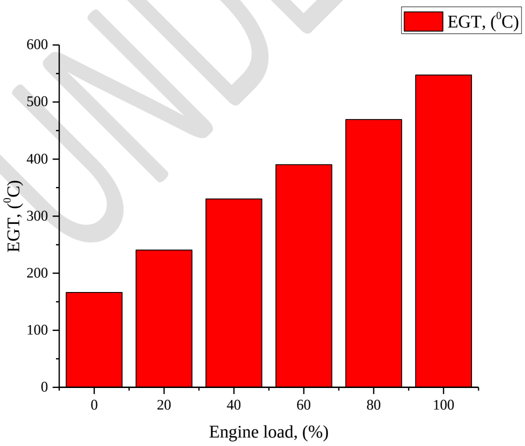

Fig. 57 Variation in exhaust gas temperature (°C) of engine with different engine loads using 100 % diesel.

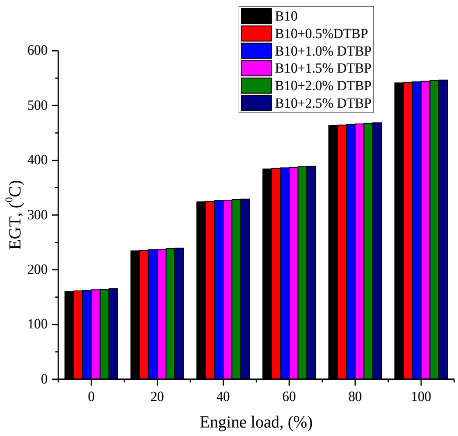

Fig. 58 Variation in exhaust gas temperature (°C) of engine with different engine loads using B10 with different proportion of DTBP

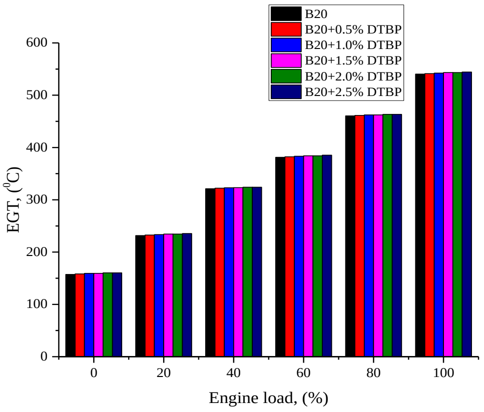

Fig. 59 Variation in exhaust gas temperature (°C) of engine with different engine loads using B20 with different proportion of DTBP

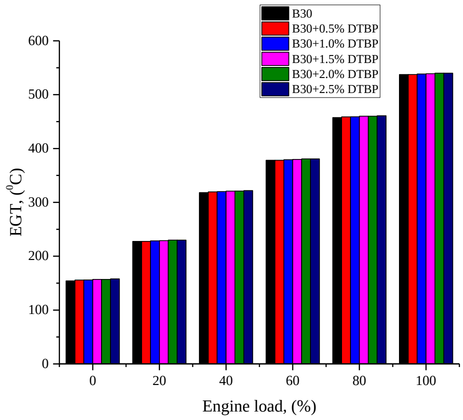

Fig. 60 Variation in exhaust gas temperature (°C) of engine with different engine loads using B30 with different proportion of DTBP

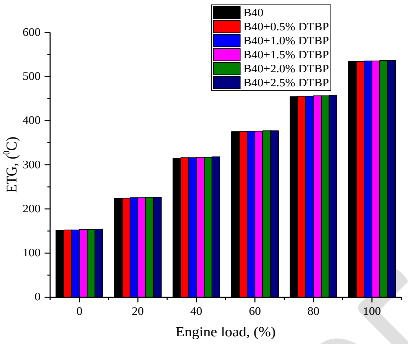

Fig. 61 Variation in exhaust gas temperature (°C) of engine with different engine loads using B40 with different proportion of DTBP

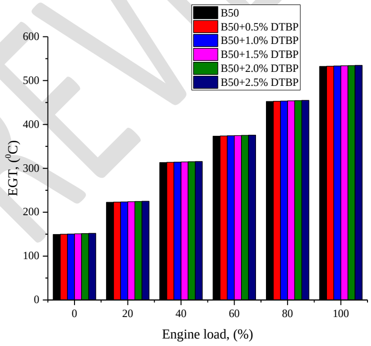

Fig. 62 Variation in exhaust gas temperature (°C) of engine with different engine loads using B50 with different proportion of DTBP

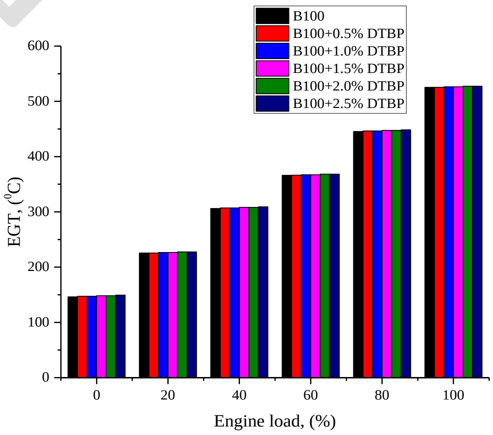

Fig. 63 Variation in exhaust gas temperature (°C) of engine with different engine loads using B100 with different proportion of DTBP

Exhaust gas temperature (°C)of CI engine was measured with different combination of blends with diesel and different load conditions. It was also showed that all the independent parameters significantly affect the exhaust gas temperature (°C)of the CI engine.

The variation in exhaust gas temperature (°C)at diesel fuel (100%), blends of biodiesel with diesel (10, 20, 30, 40, 50 and 100%) with different proportion of DTBP (0.5, 1.0, 1.5, 2.0 and 2.5%) at various load conditions (0, 20, 40, 60, 80 and 100 %) is shown in Fig. 57 to Fig. 63.The maximum and minimum in exhaust gas temperature (°C)was observed 546.53°C with $B_1A_6L_6$ and 146.32°Cwith $B_6A_6L_6$ treatment combination respectively.

f) Sound level

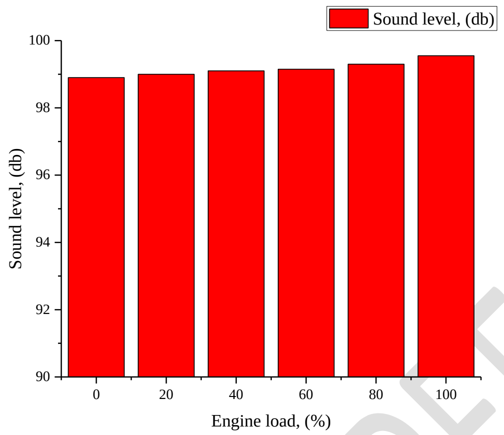

Fig. 64 Variation in sound level (db) of engine with different engine loads using 100 % diesel

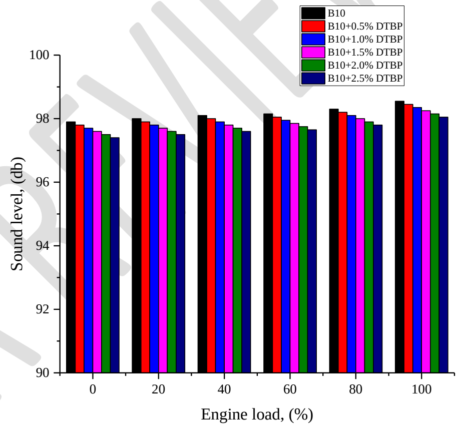

Fig. 65 Variation in sound level (db) of engine with different engine loads using B10 with different proportion of DTBP

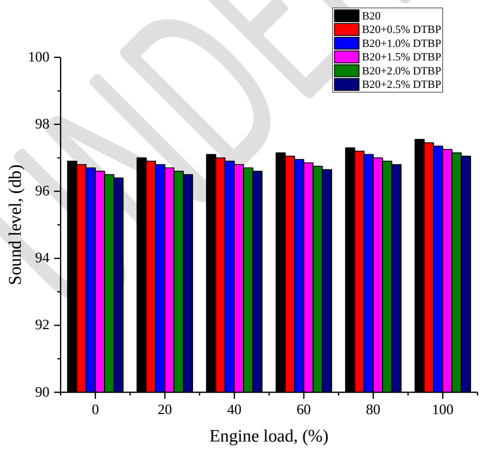

Fig. 66 Variation in sound level (db) of engine with different engine loads using B20 with different proportion of DTBP

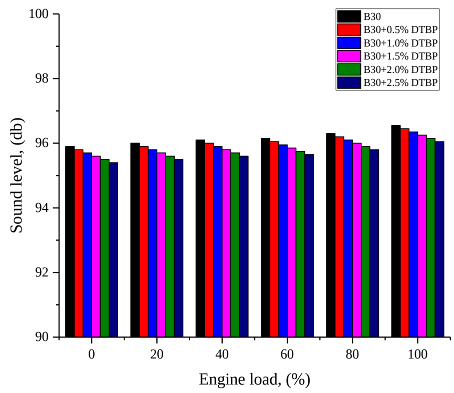

Fig. 67 Variation in Sound level (db) of engine with different engine loads using B30 with different proportion of DTBP

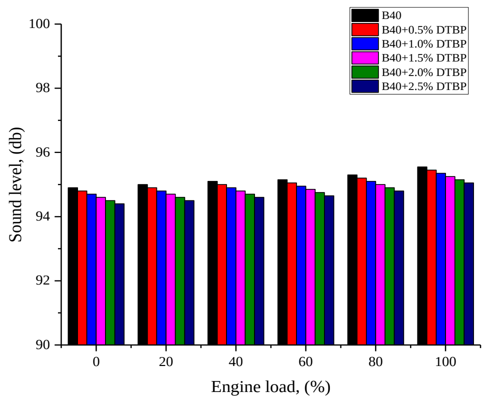

Fig. 68 Variation in sound level (db) of engine with different engine loads using B40 with different proportion of DTBP

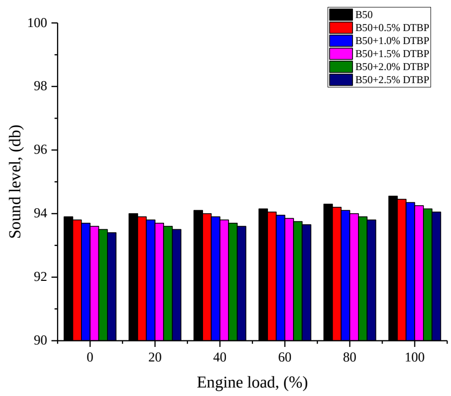

Fig. 69 Variation in sound level (db) of engine with different engine loads using B50 with different proportion of DTBP

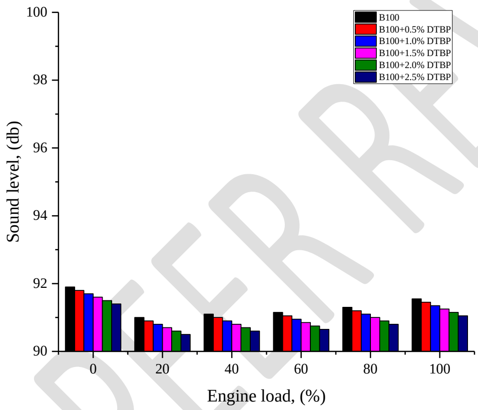

Fig. 70 Variation in sound level (db) of engine with different engine loads using B100 with different proportion of DTBP

Sound level (db) of CI engine was measured with different combination of blends with diesel and different load conditions. It was also showed that all the independent parameters significantly affect the Sound level (db)of the CI engine.

The variation in sound level (db) at diesel fuel (100%), blends of biodiesel with diesel (10, 20, 30, 40, 50 and 100%) with different proportion of DTBP (0.5, 1.0, 1.5, 2.0 and 2.5%) at various load conditions (0, 20, 40, 60, 80 and 100 %) is shown in Fig. 64 to Fig. 70.The maximum and minimum in sound level (db) was observed 90.49 (db) with $B_6A_6L_2$ and 98.55 (db)with $B_1A_1L_6$ treatment combination respectively.

As percentage of biodiesel increased as fuel in blend, sound level (db) was found to be increasing as compare diesel fuel. As per engine load was increased, sound level (db) was found to be increasing continuously. Engine load was increased, the combustion rate also increased and less time was available for the combustion and heat to dissipate to the surrounding leading to rise in sound level (db).

4. CONCLUSIONS

The maximum and minimum break specific fuel consumption was found as 0.84kg/kWh and 0.37 kg/kWh with $B_5A_1L_1$ and $B_3A_5L_5$ treatment combination, respectively. The maximum and minimum break specific energy consumption was found as 42.15 MJ/kWh and 17.51 MJ/kWh with $B_4A_6L_2$ and $B_1A_1L_6$ treatment combination, respectively.The maximum and minimum break power was found as 3.97 kWand 0.85 kW with $B_6A_5L_6$ and $B_4A_1L_2$ treatment combination, respectively.The maximum and minimum brake thermal efficiency was found as 30.55 % and 10.97 % with $B_1A_6L_6$ and $B_6A_1L_2$ treatment combination, respectively.The maximum and minimum carbon dioxide (CO_2) was found as 9.82 % and 2.2 % with $B_6A_6L_6$ and $B_5A_6L_3$ treatment combination, respectively. The maximum and minimum carbon dioxide (CO_2) was found as 0.107 % and 0.046 % with $B_1A_1L_6$ and $B_6A_6L_1$ treatment combination, respectively. The maximum and minimum nitrogen oxides (NO_X) was found as 1325 ppm and 177 ppm with $B_6A_6L_6$ and $B_1A_3L_1$ treatment combination, respectively. The maximum and minimum hydrocarbons (HC) was found as 33.69 ppm and 7.21 ppm with $B_2A_6L_6$ and $B_6A_3L_1$ treatment combination, respectively. The maximum and minimum exhaust gas temperature was found as 546.53 °C and 146.32 °C with $B_1A_6L_6$ and $B_6A_6L_6$ treatment combination, respectively. The maximum and minimum sound level was found as 90.49 (db.) and 98.55 (db.) with $B_6A_6L_2$ and $B_1A_1L_6$ treatment combination, respectively. Percentage of fuel cost saving per hour using biodiesel blends in CI Engine at full load condition with all the blends of biodiesel and diesel were 1.78, 3.61, 5.47, 7.38, 9.34 and 20.44 percentage, respectively.Percentage of fuel cost saving per hour using 50 % biodiesel + 50 % diesel + 1.5 % DTBP blends in CI Engine at full load condition was 0.23 % at best treatments ($B_5A_3L_6$).

In all types of fuel, with increased percentage of load, the brake specific energy consumption (BSEC) of the engine decreased and brake thermal efficiency, fuel consumption rate and sound level (Db) were increased respectively. The increasing in brake thermal efficiency at higher loads was due to reduction in heat losses. The brake specific fuel consumption (BSFC) is significantly higher for B100 than pure diesel. This is due to higher viscosity and low calorific value as compared with diesel. The CO emission of the biodiesel was found more than that of diesel. This may be because of the higher viscosity and lower volatility of the fuels, which lead to formation of fuel rich zones resulting in inefficient combustion thus forming CO. Diesel, on the other hand, has good fuel spray properties and lower viscosity, which enable it to mix efficiently with air, burn evenly and hence emit lesser

CO. The HC emissions of the B10, B20, B30, B40 and B50 fuel decreases with increases blend. This may be due to the presence of rich fuel air mixture at higher loads. On the other hand, the NO_x emission was increased with increased biodiesel blend in diesel. The CO emission of the B10, B20, B30, B40 and B50 fuel was found to be more than that of diesel. This may be because of the higher viscosity and lower volatility of the fuels, which lead to formation of fuel rich zones resulting in inefficient combustion thus forming CO. Diesel, on the other hand, has good fuel spray properties and lower viscosity, which enable it to mix efficiently with air, burn evenly and hence emit lesser CO.

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