The Effect of Linseed Diesel Blends and Nano additives on Diesel Engine Performance and Emission Characteristics

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Abstract

To meet human needs, the world is seeing a widespread demand for fuels. Different fuel systems/modes, such as gasoline and diesel, are becoming more expensive, necessitating the development of alternative fuels that emit fewer emissions and enable more efficient operation. Combustion engines, such as conventional petrol and diesel engines, run on crude oil, and crude oil reserves in the earth's crust are rapidly decreasing. To bring the eco system back into balance and reduce emissions, we must rely on alternative fuels, which emit less carbon and are a good substitute for current oils. The gases released as a result of the combustion will have an impact on the human environment as well as the environment's eco system, including birds, plants, and other living things. The ozone layer will be immediately affected by the release of these carbon-containing chemicals. This has a significant impact on the ozone layer's ability to protect us. Biofuels are the most common alternate approach for addressing these issues. Biofuels will have significant green effects while emitting relatively little carbon dioxide. Temperature and pressure changes will be much reduced in these biofuels. The linseed biodiesel has been prepared for the present study by transesterification process, and the percentage of biodiesel added to the diesel fuel is 30% by volume. Nano additives such as Al_2O_3 and TiO_2 were used as additives to fuel blends. The concentration of each (Al_2O_3 and TiO_2) nanoparticles varied in the fuel blend is 50ppm and 100ppm. For the research, a single cylinder water-cooled diesel engine was used. The constant injection pressure and compression ratio is maintained by 240bar and 16.5. The load on the engine varied by 25% to 100% in the steps of 25. From the results, it was observed that the addition of nano additives improves the Brake Thermal Efficiency (BTE) and reduces the Brake Specific Fuel Consumption (BSFC) of the engine. Nano additive fuel blends reduced NOx, CO, HC, and smoke emissions considerably when compared to diesel fuel. The results revealed that nanoparticles with 100ppm blended fuels showed improved engine working characteristics compared with other fuel blends. It was also noticed that Al_2O_3 nanoparticles blended fuel showed better performance compared to TiO_2 nanoparticles fuel blend.

Keywords: Diesel Engine, Linseed Biodiesel, Al_2O_3 Nanoparticles, TiO_2 Nanoparticles, Engine characteristics.

1. Introduction

The human society is using the different forms of the energy sources. The fossil fuels are proving them as very efficient form of resources on the earth. As the transportation is growing and the automobile industry is upgrading day by day, newer forms of the energy sources are developing to meet the requirements of the transportation system. However, these fossil fuels are more efficient and the emission rate is below 30% compared to conventional forms of the energy sources. The minerals required to extract oil from the earth's crust are nonrenewable energy sources that will run out in the near future. According to analysts, the coal reserves we use today have a history of several lakh years and will survive for another 200 years in the future. As a result, there is a pressing need to produce a fuel that is both environmentally friendly and renewable. Global warming is caused by excessive fuel consumption by the earth's crust, and the temperature is rising at a rate of 5°C every year. The technology in the petroleum and the oil industry must be re created to fit for the healthy environment. So we have the option of bio fuel to make it wide spread t reduce the future consequences. The rapid increase in the population will also increase the movement of people. This movement is based on the machines which uses the fuels to do work, so the biologically useful fuel may some what reduce the effects and make the atmosphere clean. Therefore there is a need for fuel which produces less carbon and contributes to the sustainable development.

Some of the bio fuels which we are experimenting is Linseed B30 , the fuel will be subjected to many experimental procedures to determine the efficiency of the fuel, emission of the carbon content, performance of the fuel , rate of temperature and pressure variations with or without additives etc. From the results, we can analyse that how will be the performance of the fuel contributing to the energy resources? When subjected to the combustion engine, what will be the brake power, efficiency, specific fuel consumptions etc? After the usage of the Linseed B30 with and without additives, what will be the efficiency effect on the diesel engine.

Mandal and Kanagaraj (2012) attempted a study of the enhanced combustion efficiency of CI engines by adding CeO2 nanoparticles into diesel. SDS surfactant was used, and the mixing was done using a tip sonicator for the various concentration of CeO2, i.e., 0.02, 0.04, 0.06, 0.08, and 0.10 wt. % in diesel. By affecting the complete combustion of fuel, cerium concentration in diesel has a significant role in limiting the emission of poisonous gases. The higher elimination of emission gases and increased engine performance were recorded at an average of 75 % of load and 0.06 wt % of CeO2 nanoparticles in diesel. Because the BTE has risen by 10% while the mechanical efficiency has increased by 7%, the engine's performance has also improved. NOx, HC and CO emission were decreased by 10 %, 50 %, and 40 %, respectively.

Lenin et al. (2013) compared diesel engine performance and emission parameters using diesel fuel containing 100 mg/L manganese oxide (MnO) and CuO nanoparticles. For all loads, the BTE of MnO blend was higher than CuO blend. The BTE of pure diesel and diesel+CuO fuel were almost identical. At all loads, CO and NOx emissions from MnO blend were lower than those from pure diesel and CuO blend. At all load circumstances, the emission HC for pure diesel, CuO, and MnO blends was essentially identical.

Santhanamuthu M et al. (2014) had studied the thermal performance of CI engine with Polanga oil and diesel blend (POD) with iron oxide nanoparticles. POD iron oxide nanoparticle mixes have BTE and BSEC that were comparable to neat diesel. CO emissions for POD iron oxide nanoparticle blends were within 5%. The HC and smoke emissions from POD iron oxide nanoparticle mixes was 10-15% lower than that of pure diesel at a load more than 80%.

The effects of adding oxygen-containing nanoparticle additions to biodiesel on fuel characteristics, diesel engine performance, and exhaust emissions were explored by Ozgur et al. (2014). They utilised two distinct nanoparticle additives, MgO and silicon oxide (SiO2), at 25 and 50 ppm, respectively. With the inclusion of nanoparticles, their results revealed that engine emissions of NOx and CO were reduced, while engine performance was somewhat improved.

Mirzajanzadehet al. (2014) investigated the performance and emission characteristics of CI engines using a hybrid nanocatalyst (CeO_2+Multi walled carbon nanotube) in diesel and waste cooking biodiesel blends (B5 and B20). The hybrid nanocatalyst was added to dosage levels of 30, 60, and 90 ppm. The use of a hybrid nanocatalyst resulted in an improvement in engine torque and output. When comparing B20 (90 ppm) to B20, the largest gain in power and torque was 7.81 percent and 4.91 percent, respectively. When it comes to BSFC, B20 (90 ppm) showed a maximum reduction of 4.50 percent when compared to B20. CO, HC, NOx, and soot could be reduced because to CeO_2 nano additions' unique oxygen absorption and donation characteristics. CeO_2 is supported by a multi-walled carbon nanotube (MWCNT). When B20 (90 ppm) was compared to neat B20, the greatest CO, HC, NOx, and soot reductions were 18.9, 38.8, 71.4, and 26.3 percent, respectively. The MWCNT functions as a catalyst, speeding up the burning process and lowering the ID. CeO_2 nanoparticles operate as an oxygen-donating catalyst, oxidising CO to CO_2 and absorbing oxygen, converting NOx to nitrogen. CeO_2's activation energy burns away carbon deposits in the combustion chamber, reducing HC and soot emissions.

Sarvestany et al. (2014) investigated the performance and emission characteristics of diesel engines with Fe3O4 magnetic nanoparticles dispersed in the fuel at 0.4 and 0.8 vol percent concentrations. The combustion parameters of the nanofluid fuel with a nanoparticle concentration of 0.4 vol percent were superior than those of the 0.8 vol percent concentration. The BSFC values for 0.4 vol percent nanofluid fuel were lower than those for neat diesel, whereas the BSFC values for 0.8 vol percent nanofluid fuel were higher than those for neat diesel and 0.4 vol percent fuels. Experiments also demonstrated that increasing the dosage level of nanoparticles reduced NOx and SO2 emissions while increasing CO emission and smoke opacity. Because Fe3O4 nanoparticles absorb oxygen, they reduce NOx emissions, with average reductions of roughly 56 percent and 67 percent in the cases of 0.4 vol percent nanofluid and 0.8 vol percent nanofluid fuels, respectively, when compared to neat diesel. When 0.4 vol percent nanofluid and 0.8 vol percent nanofluid fuels were compared to neat diesel, sulphur dioxide (SO2) emissions fell by 14 percent and 20 percent, respectively.

Subramaniam, (2013) The oil resources are widely used and to increase the economy of the respective countries, the utilization and the exploitation of the natural resources are taking place. The major development in the automobile industry paved the way for the newer generation vehicle, and the engine development form the BS4 to BS6 now, reduced the emission and the refinement of the engine also. The newer option of the engine will let the specific fuel consumption low thereby contributing to the best efficient fuel forms. The people in the modern era are using the petrol and diesel as main forms of energy resources to run the vehicles in addition to compressed natural gases.

2. Materials and methods

Super India Enterprises, India, supplied the linseed oil. Diesel fuel was procured from a nearby city. The size of Al_2O_3 is 30-50nm and TiO_2 nanoparticles is in the range of 10-20nm were purchased from a nano research lab. The characteristics of nanoparticles are provided in Table 1.

Table 1. Properties of nanoparticles

Item	Specifications	
Manufacturer	Nano Research Lab, India	Nano Research Lab, India
Molecular formula	Al_2O_3	TiO_2
Average particle size	30 – 50nm	10-20 nm
Color Appearance	White	White
Morphology	Spherical	Spherical
Purity	99.9%	99.9%
Bulk density	1.5 g/cm^3	0.15-0.25 g/cm^3
True density	3.97 g/cm^3	4.23 g/cm^3
Atomic Weight	101.96 g/mol	79.865 g/mol
Specific surface area SSA	120-140 m^2/g	200-220 m^2/g

2.1 Fuel blends preparation

The process of alkaline transesterification converts raw linseed oil into linseed oil methyl ester (LOME). To make a methoxide solution, a sodium hydroxide of 1% volume was mixed in a methanol solution of 20% volume and agitated using a magnetic stirrer. With the help of an ultrasonicator, heated raw linseed oil to 60°C, thereafter methoxide solution was mixed with the linseed oil. The mixture was agitated for one hour, and the oil was separated into a separating funnel. With gravity, oil in a separating funnel settles into two layers after 24 hours. The upper portion of the separating funnel contained crude LOME, while the lower contained glycerol. Now separate the crude LOME from glycerol and thereafter wash with the water. The crude LOME was heated up to a temperature of 100°C to detach the water content in oil, and to make oil as clean LOME.

2.2 Nanoparticle characterization and Blend preparation

This investigation used diesel-biodiesel blends with and without TiO_2 and Al_2O_3 nanoparticles as test fuel blends. The results of scanning electron microscopy (SEM) examinations to assess the characteristics of TiO_2 and Al_2O_3 nanoparticles are shown in **Figure 1**. The surface morphology and shape of TiO_2 and Al_2O_3 nanoparticles were determined using SEM. A magnetic stirrer was used to prepare different fuel blends containing various nanoparticles in the biodiesel-diesel blend. With their respective compositions, the different types of fuel blends are depicted in Table 2. The ASTM standard procedure was used to determine the properties of different fuel blends. The properties of various fuel blends are shown in Table 3.

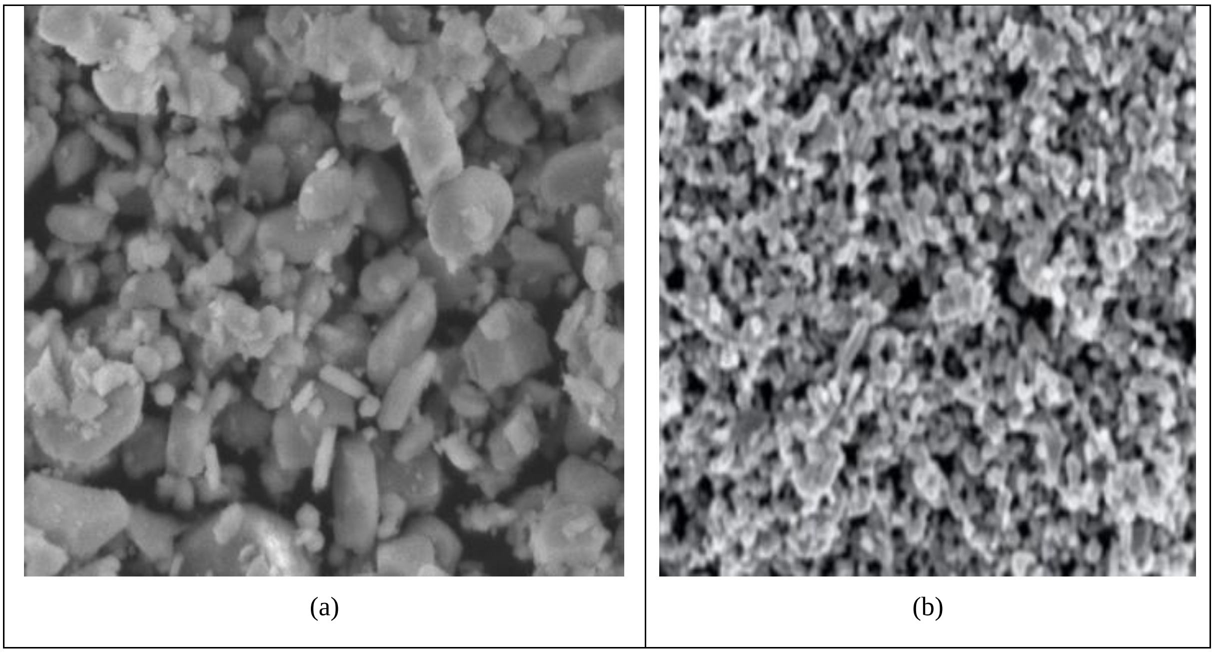

Figure 1. SEM image of (a) TiO_2 (b) Al_2O_3

Table 2. Types of blends with composition

Blend Name	Composition
Diesel	0% Biodiesel + 100% Diesel
DB30	30% Biodiesel + 70% Diesel
DB30T50	30% Biodiesel + 69.95% Diesel + 50 PPM TiO_2 nanoparticles
DB30T100	30% Biodiesel + 69.9% Diesel + 100 PPM TiO_2 nanoparticles
DB30A50	30% Biodiesel + 69.95% Diesel + 50 PPM Al_2O_3 nanoparticles
DB30A100	30% Biodiesel + 69.9% Diesel + 100 PPM Al_2O_3 nanoparticles

Table 3. Properties of test fuels

3.

Properties	Diesel	DB30	DB30T50	DB30T100	DB30A50	DB30A100
Density (kg/m^3)	825	843	845	847	846	848
Viscosity (mm^2/s)	3.40	3.59	3.62	3.65	3.63	3.67
Flash point (K)	324	343	347	351	346	350
Calorific value (MJ/kg)	43.2	41.0	41.3	41.9	41.5	42.1

Experimental setup

Figure 2 depicts a schematic representation of an experimental test setup. To load the diesel engine, a hydraulic dynamometer was employed. Table 4 lists the test rig's specifications. Several fuel measurement sensors, digital load sensors, and airflow rate sensors are integrated with the engine set up in a data acquisition system (DAS) configuration. Engine Soft software is employed to evaluate a diesel engine's performance parameters. HC, CO, and NOx emissions from the diesel engine have been evaluated with the help of a multi-gas emission analyzer. A smoke meter measures the amount of smoke exhausted from the diesel engine.

Figure 2. Schematic view of an experimental test rig

Table 4. Specifications of a test rig

Parameters	Specifications
Engine	Kirloskar VCR Diesel Engine
Type	4-Stroke One Cylinder
Make	Tech Ed Equipment Company
Stroke Length	110 mm
Connecting rod length	234mm
Bore	80 mm
Power Capacity	4 KW
Compression ratio	16
Engine CC	552 CC
Injection Pressure	240 bar
Dynamometer	Hydraulic dynamometer
Speed	1500 rpm
Cooling type	Water Cooled Engine

4. Results and Discussion

The following sections investigates the impact of fuel blends on engine performance and emission characteristics.

4.1 Brake Thermal Efficiency (BTE)

The section describes the brake thermal efficiency of different fuel blends at various Indicated Powers (IPs). It has been found that increasing the engine's IP raises the BTE, which is determined to be higher at higher IP. The possible reason for this is increased injection pressure increases the fuel atomization in the combustion chamber, which increases the fuel oxidizer contact, accelerated momentum in the fuel distribution also improves the combustion resulting in increased BTE. The maximum BTE was found at 240 bars for DBL30T100 and DBL30A100 blend as compared to other blends and minimum was found at 200 bars. The BTE of DBC30T100 and DBC30A100 blend at IP of 200 bar is 30.6% and 31.2%, at 220 bar is 31.3% and 31.9%, and at 240 bar is 32.2% and 32.8%. The increase in BTE for diesel, DBL30, DBL30T100 and DBL30A100 blend blend is 5.59%, 5.71%, 5.23% and 5.13% by increasing the injection pressure from 200 to 240 bars.

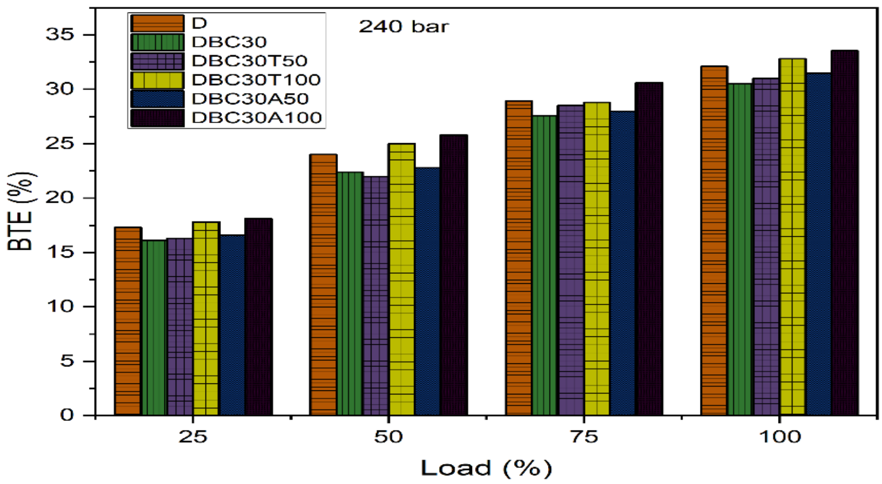

Fig. 3 BTE of various fuel blends with respect to load

4.2 Brake Specific Fuel Consumption (BSFC)

BSFC describes the amount of fuel consumed for unit power output. The BSFC of various fuel blends at different loads was depicted in Fig. 4. The lower BSFC was found at IP of 240 bar for all fuel blends, whereas the higher BSFC was observed at IP of 200 bar. From the results, it has been found that at all IP DBL30T100 and DBL30A100 blend shown lower BSFC as compared to other fuel blends. The BSFC of DBL30T100 and DBL30A100 blend at 200 bars, 220 bar and 240 bar is 0.275 and 0.27, 0.264 and 0.259, and 0.249 and 0.244 kg/kW hr. The amount of reduction in the BSFC by increasing the IP from 200 to 240 bar is 10.23%, 9.45% and 9.63% for diesel, DBL30T100 and DBL30A100 blend. The reduction in the BSFC for DBL30T100 and DBL30A100 blend at 240 bars compared with diesel fuel is 1.58% and 3.56%.

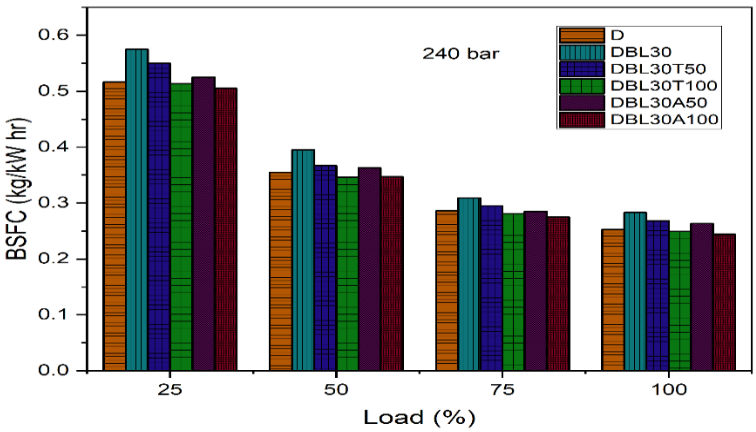

Fig. 4 BSFC of various fuel blends with respect to load

4.3 Carbon Monoxide emission (CO)

It describes that increasing the injection pressure lowers the formation of CO emissions for all fuel blends. It has been observed that at 240 bar lower CO was found foe all fuel blends compared with 200 and 220 bar injection pressures. The possible reason for this is increased injection pressure increases the fuel atomization in the combustion chamber, which increases the fuel oxidizer contact, accelerated momentum in the fuel distribution also improves the combustion resulting in decreased CO emissions. The rate of reduction in CO emissions for diesel, DBL30, DBL30T100 and DBL30A100 blend is 13.13%, 12.24%, 13.19% and 13.64%. The reduction in CO emissions compared with diesel fuel for DBL30T100 and DBL30A100 blend is 8.14% and 11.63% at 240 bars injection pressures.

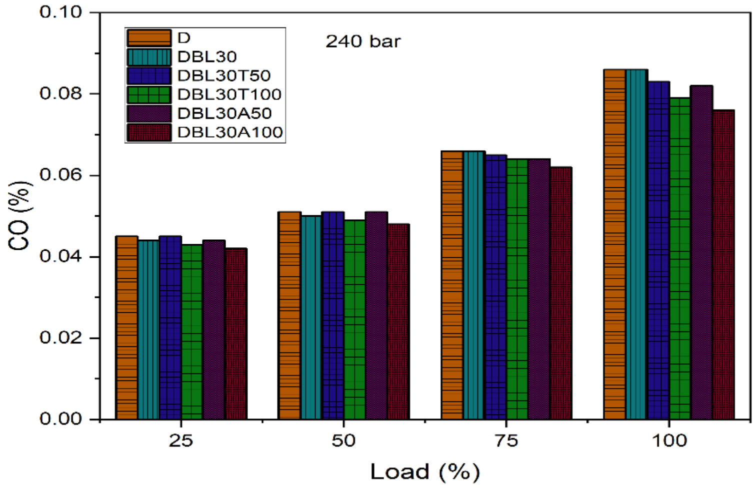

Fig. 5 CO of various fuel blends with respect to load

4.4 Hydrocarbon emission (HC)

The reduction in HC emission was observed with the increased IP from 200 to 240 bars. From the results, it has been observed lower HC emission was found at 240 bars IP, whereas higher HC emission was found at 200 bars. The reason for this is due to improved atomization and increased spray length with increased injection pressure. Also, due to high-pressure injection, the quenching zones were lowered or a reduction in the flame quenching distance. Nanoparticles incorporated linseed biodiesel blend shown lower HC emissions compared to diesel fuel and linseed biodiesel blend at all IP's. The amount of reduction in HC emissions with increased IP from 200 to 240 bar is 11.19%, 11.86%, 13.21% and 14% for diesel, DBL30, DBL30T100 and DBL30A100 blend. In comparison to diesel fuel, the amount of reduction in HC emission for DBL30T100 and DBL30A100 blend is 17.86 % and 23.21%at 240 bar injection pressure.

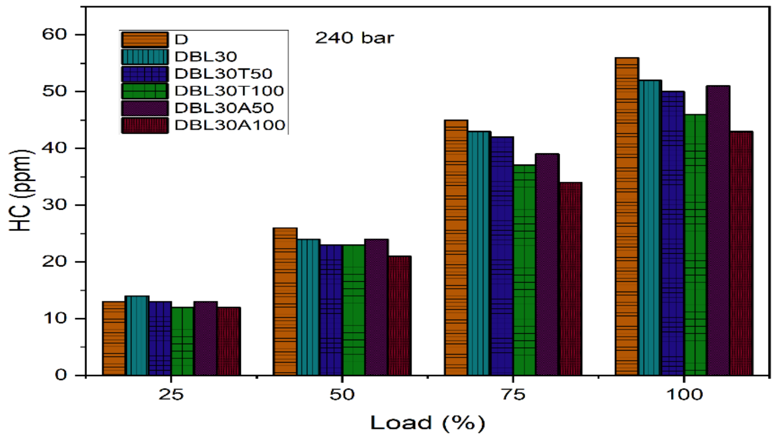

Fig. 6 HC of various fuel blends with respect to load

4.5 Oxides of Nitrogen emission (NOx)

The experimental results show that the NOx emissions increases when IP is increased shown in Fig 7. The minimum NOx was observed at 200 bar IP for all fuel blends and maximum NOx was observed at 240 bar IP. This is because at this IP, the fuel sprayed completely diffuses with air in the combustion chamber which improves the complete burning resulting in increased NOx. The amount of increase in NOx emissions by increasing the IP from 200 to 240 bar is 12.1%, 10.26%, 11.73% and 11.49% for diesel, DBL30, DBL30T100 and DBL30A100 blend. In comparison to other fuel blends, the DBL30T100 and DBL30A100 blend produced lower NOx at all IP's. For DBL30T100 and DBL30A100 blend compared with diesel fuel, at full load, the BTE increases by 5.9% and 3.93% at 200 bar, 5.94%.

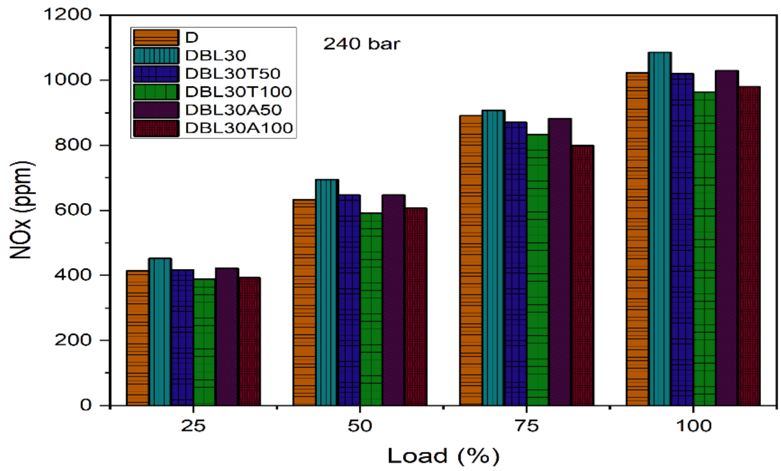

Fig. 7 NOx of various fuel blends with respect to load

4.6 Smoke emission

Experimental results show that the smoke emission decreases when IP is increased from 200 to 240 bars shown in Fig.8. smoke emissions of DBL30T100 and DBL30A100 blend blend shown lower at all IP compared to diesel and linseed biodiesel blend. It is attributed to the increased fuel IP increases the fuel atomization that improves the fuel-air mixing and rate, which enhances the combustion resulting in lower smoke emissions. The reduction in smoke emissions by increasing the IP from 200 to 240 bars is 2.84%, 2.6%, 3.01% and 3.4% for diesel, DBL30, DBL30T100 and DBL30A100 blend. The lower BSFC was observed at 200 bars for diesel fuel, DBC30T100 and DBC30A100 blend is 4.58, 4.01 and 3.87 BSU. The percentage of BSFC reduction for DBC30T100 and DBC30A100 blend is 12.58% and 15.73% compared to diesel fuel at 240 bars.

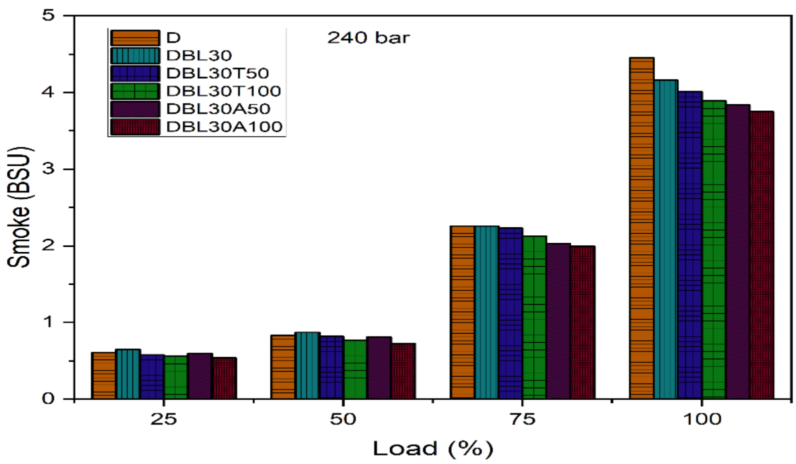

Fig. 8 Smoke of various fuel blends with respect to load

5. Conclusions

The influence of several nano additives introduced into a biodiesel mix on diesel engine performance and emission characteristics was explored in this study. Experiments on a diesel engine with a constant speed of 1500 rpm under varying loads were carried out. For all fuel mixes, performance measures such as BTE and BSFC, as well as emission characteristics such as HC, NOx, CO, and smoke, were assessed. The results achieved using nanoparticle fuel blends were compared to pure diesel, and the following conclusions were drawn. This phase of research is carried out with 50 ppm and 100 ppm Al_2O_3 and TiO_2 nanoparticles blended with diesel-linseed biodiesel blend. The conclusions are summarized by following optimum values:

- When compared to pure diesel, the BTE improvement for DBL30T100 and DBL30A100 blends is 5.10 percent and 5.20 percent, respectively.
- When compared to pure diesel, the BSFC of DBL30T100 and DBL30A100 blends is 1.51% and 3.51% lower, respectively.
- The DBL30T100 and DBL30A100 blends had reported the CO emissions reductions of 8.11 percent and 11.60 percent, respectively compared to pure diesel.
- The highest reductions in NO_x emissions for DBL30T100 and DBL30A100 blends is 5.91% and 4%, respectively.
- HC emissions decreased by 17.81 % and 23.19% for DBL30T100 and DBL30A100

blends compared to diesel fuel.

- Smoke emissions were significantly decreased by 12.48% and 15.13% respectively, while using DBL30T100 and DBL30A100 blends.

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