EFFECT OF INJECTION PRESSURE ON PERFORMANCE AND EMISSION CHARACTERISTICS OF DIESEL ENGINE OPERATED WITH WASTE PLASTIC DEPOLYMERIZED BIODIESEL BLEND WITH THERMAL BARRIER COATED PISTON.

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Abstract
In the present research work, the fuel derived from refuse waste plastic was taken as an alternative fuel. The alternative fuel was blended with conventional diesel in various blends like B10, B20, B30, and B40, and aluminium oxide nanoparticles were added to the fuel by 50,100,150, and 200PPM for the reduction of exhaust gas emissions of the engine. The fuel injection pressure is one of the crucial factors which influence the performance and emission of diesel engines. The injection pressure was varied by adjusting the fuel injector spring tension. In this research work, various alternative fuel blends were tested on the engine with a zirconium-coated piston surface and the blend B30 has given better combustion and emission characteristics when compared with other biodiesel blends. Then the injection pressure was varied by a pressure of 210 Bar, 220 Bar, and 230 Bar for the optimal blend B30, and the performance and emission characteristics of the engine were evaluated at different injection pressures.

Keywords: Waste plastic biodiesel, zirconium coated piston, aluminium oxide nano additives, environmental pollution, injection pressure.

1. Introduction

The rapid depletion of fossil fuels and the ever-increasing prices of crude oil and made researchers search for alternative energy sources. The scarcity of fossil reserves will make renewable energy resources more attractive. The most feasible way to meet the growing demand for fossil fuels is by utilizing alternative fuels. Alternative fuels are eco-friendly, sustainable, and renewable which reduces the dependency on fossil fuels and they help to preserve the atmosphere by reducing engine exhaust emission levels. Burning fossil fuels creates higher levels of carbon dioxide and other harmful gases in the atmosphere, affecting the greenhouse effect. The scarcity of conventional fossil fuels, increasing emissions of combustion-causing pollutants, and their increasing costs will make biomass sources more attractive. The main objective of this work is to effectively utilize the depolymerized waste plastic biodiesel as a substitute fuel for diesel and to greatly improve the performance of the engine and reduce the harmful emissions caused by the engine. Thermal barrier coating is to be used for coating the piston top surface which reduces the heat loss from the engine and reduced carbon monoxide and hydrocarbon emissions. To effectively utilise aluminium oxide nano particles for improving the performance and emission characteristics of the engine.

2. Blend Preparation

The alternative fuel blends were prepared separately with a combination of diesel like B10, B20, B30, and B40. The B10 blend consists of 100 ml of waste plastic biodiesel, 900 ml of diesel, and 50 ppm of aluminium oxide nanoparticles, B20 consists of 200 ml of waste plastic biodiesel, 800 ml of diesel and 100 ppm of aluminium oxide nano particles, B30 consists of 300 ml of waste plastic biodiesel, 700 ml of diesel and 150 ppm of aluminium oxide nano particles, and B40 consists of 400 ml of waste plastic biodiesel, 600 ml of diesel and 200 ppm of aluminium oxide nano particles. In this research, aluminium oxide nanoparticles were doped into the fuel blends with the help of an ultrasonicator. The ultra-sonication is the best method for scattering between the nanoparticles in fluid, fit for staying in suspension for a long time. Ultrasonic waves were made in liquid interference by soaking an ultrasound test in suspension. The properties of diesel fuel and depolymerized waste plastic biodiesel (W.P.D) and their blends were evaluated to find out the properties of density, kinematic viscosity, flash point, and calorific values of diesel and biodiesel blends which are tabulated in table 1.

Table 1 Properties of diesel and biodiesel blends

Property	Diesel	Waste plastic biodiesel	B10	B20	B30	B40
Density	835	794	847	855	862	868
Kinematic Viscosity	3.10	2.13	3.6	4.43	4.6	4.62
Flash point	52	42	50	47	45	44
Fire point	58	45	54	52	51	50
Calorific value	42744	42108	42314	41536	41488	41463

3. Engine Modification

The piston modification was done by coating the piston with thermal barrier coating. The Thermal Barrier coating resists the amount of heat loss from the engine. Yittria-stabilized zirconia (Y.S.Z) was used to coat the piston top surface which has a very low conductivity and high melting point. Thermal barrier coating performs important functions of insulating the components such as aero-engine parts, and gas turbines which operate at a very high temperature. The coating to the piston surface was deposited with the help of the plasma spraying technique, where the total thickness of the ceramic coating is 550 microns. The pre-coat of the substrate material is NiCrAlY alloy of 150 microns, aluminium oxide was used as bond-coat material which contains a thickness of 200 microns and the top coat consists of yittria stabilized zirconium of 200 microns.

4. Experimental Work

The investigation of engine performance and emission characteristics were performed by using a single-cylinder, Kirloskar make direct injection diesel engine with yittria stabilized zirconium coated piston surface. The specifications of the Kirloskar engine are tabulated in table 2. The forced circulation, water-cooled eddy current dynamometer was used as a test rig for experimental work which is shown in figure 1. The engine was coupled with a piezo-type cylinder pressure sensor, electromagnetic pick-up, and thermocouples to measure the various temperatures of the engine. The manometer is used to measure the airflow and fuel rates, and the rotameter is to measure the water flow rate of the engine.

Table 2. Specifications of the engine

Specification	Type
Rated Speed	1500 RPM
Cylinder Bore	80 mm
Stroke Length	110 mm
Compression Ratio	18
Length of Connecting Rod	234 mm
Brake Power	5 Kw
Engine	4 Stroke single cylinder, Direct injection
Make	Kirloskar Engine
Type of Cooling	Forced circulated water-cooled system
Type of Engine	Compression Ignition Diesel Engine

Fig. 1 Experimental setup of the engine

The performance and emission analysis were done in two stages. In the first stage of experiment, various blends of alternative fuels like B10, B20, B30, and B40 were tested on single-cylinder, direct-injection diesel engine to find the optimal blend results in terms of performance and emission characteristics of the engine. It was found from the investigation that blend B30 has given better performance and emission characteristics when compared with diesel.

In the second stage of experiment, the blend B30 was taken and the injection pressure of the engine was varied by 210 bar, 220 bar, and 230 bar. The injection pressure of the engine was varied by fuel injector spring tension. The performance and emission characteristics of the engine was investigated by increasing the injection pressure.

5. Results and discussions

5.1 Load Vs Brake Specific Fuel Consumption (B.S.F.C)

The variation of brake specific fuel consumption (B.S.F.C) with load is shown in figure 2. The figure itself reveals that as the load increases brake specific fuel consumption decreases. It can be observed from the figure the brake specific fuel consumption of diesel with normal piston was 0.5 Kg/kwh at full load condition whereas for diesel with thermal barrier coating piston it occurred at 0.4 Kg/kwh. For biodiesel blend B30 the brake specific fuel consumption was optimal with 0.39 Kg/kwh at full load condition when compared with other blends. As the injection pressure increases from 210 bar to 230 bar the brake specific fuel consumption decreases from 0.41 Kg/kwh to 0.35 Kg/kwh due to better refinement and atomization of the fuel particles, and the BSFC was decreased by 17.14%.

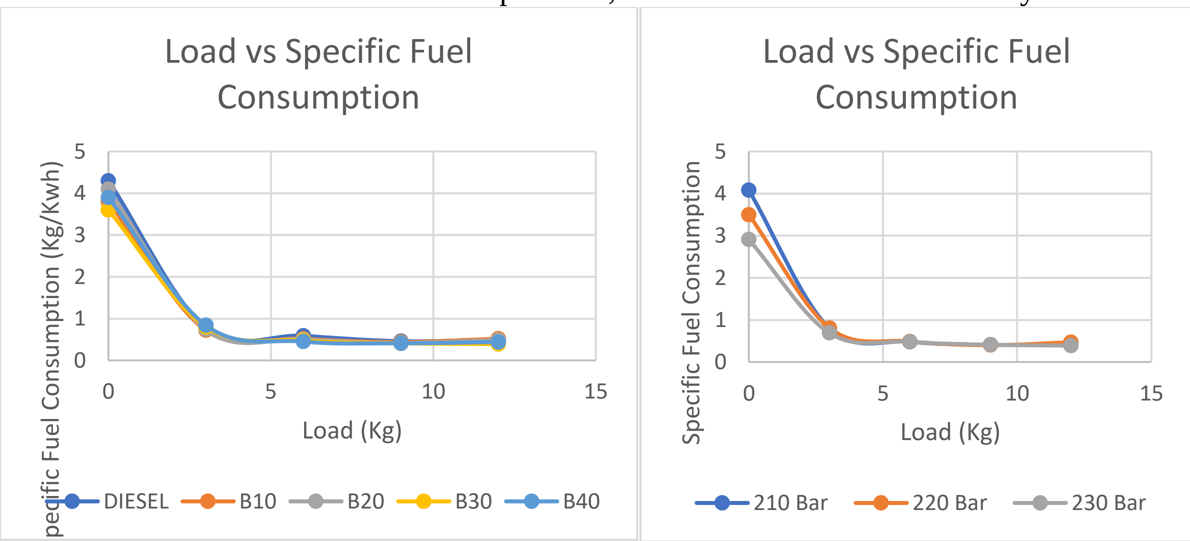

Fig 2 B.S.F.C for various biodiesel blends and injection pressures

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5.2 Load Vs Brake Thermal Efficiency (B.T.E)

The variation of brake thermal efficiency (B.T.E) with load is shown in figure 3. The figure reveals that, as the load increases the brake thermal efficiency increases. The maximum brake thermal efficiency for diesel with normal piston occurred at 17.11% and at 19.67% for coated piston, whereas for the biodiesel blend B30 the maximum brake thermal efficiency occurred as 20.21% at full load condition. The variation of brake thermal efficiency as the injection pressure increases from 210 bar to 230 bar the brake thermal efficiency occurred at 25.45%. The variations of BTE for the diesel injected at different injection pressures i.e; 210bar, 220bar and 230bar as a function of engine speed. The Thermal efficiency was an indicator of the amount of energy which is released by the fuel during the combustion and transformed into useful work, compared to fuel injected at 210bar injection pressure, diesel injected at 220bar and 230bar having higher BTE. Compared to fuel injected at 210 bar, the fuel injected at 230bar injection pressure has increased brake thermal efficiency of 25.92%.

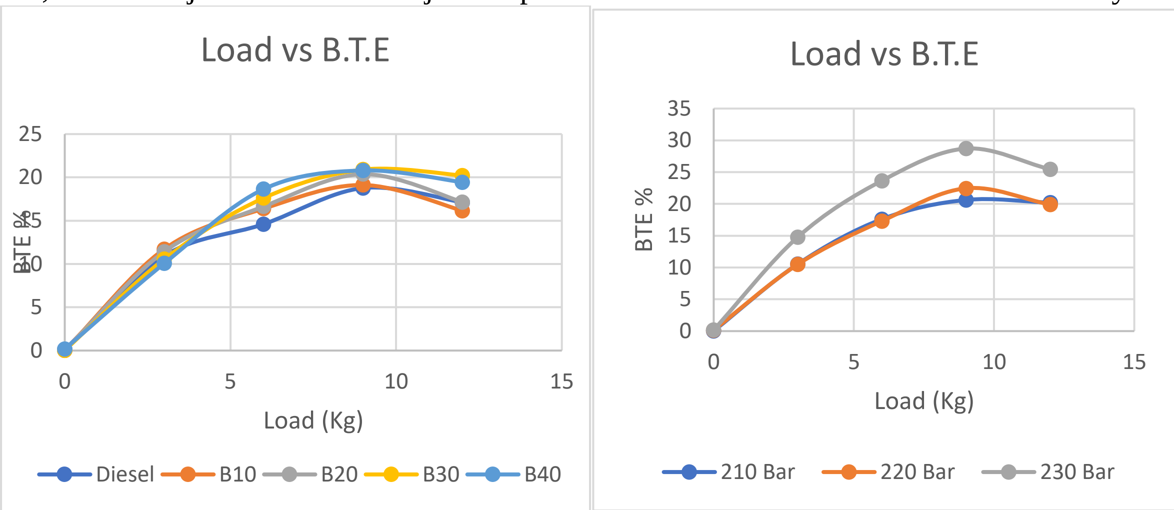


Fig 3 B.T.E for various biodiesel blends and injection pressures

5.3 Load Vs Mechanical Efficiency

The variation of mechanical efficiency with load is shown in figure 4. The figure reveals that as the load increases the mechanical efficiency increases. The mechanical efficiency for diesel was obtained as 82.46% with normal piston at full load condition and 83.34% for coated piston, whereas for B30 it was obtained as 86.77% at full load condition. As the injection pressure of the engine increases the maximum mechanical efficiency was obtained at 230 bar which was obtained at 70.36%.

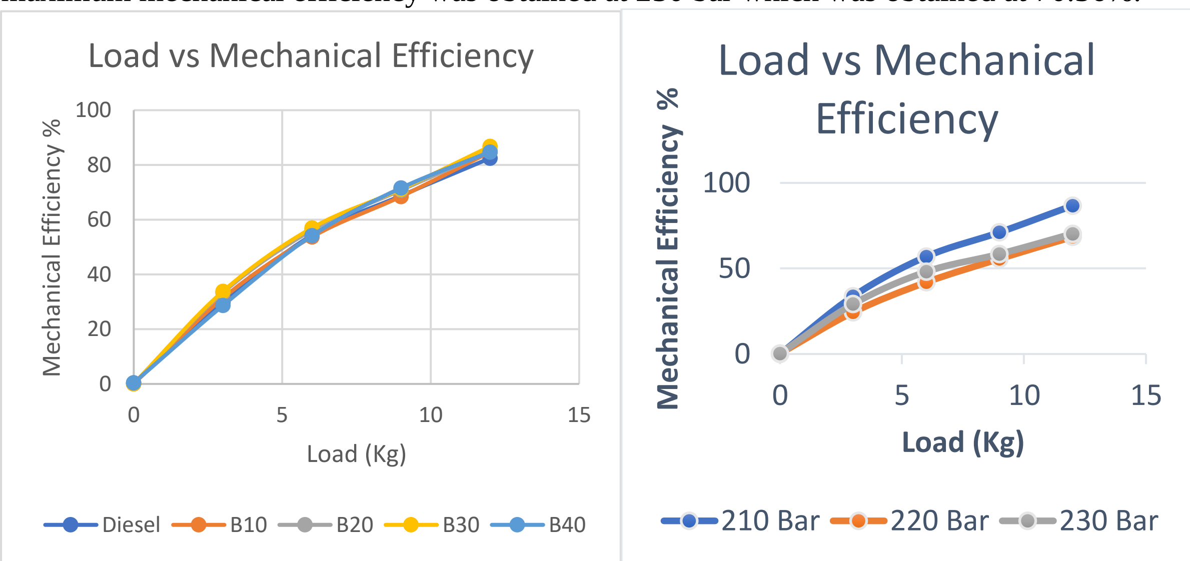
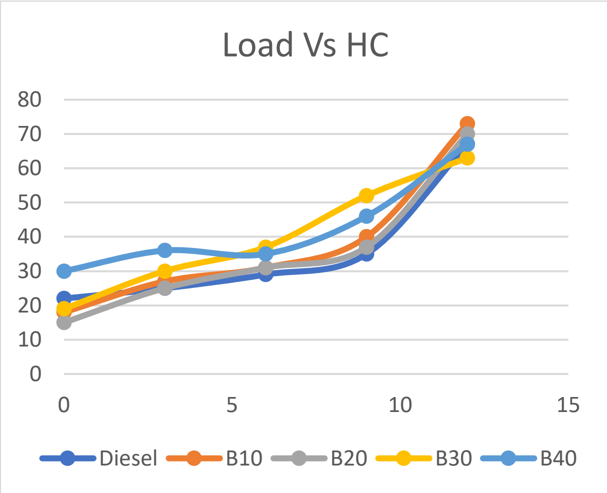


Fig 4 Mechanical efficiency for various biodiesel blends and injection pressures

5.4 Load Vs Hydrocarbons (H.C)

The variation of hydrocarbons with load is shown in figure 5. The figure reveals that as the load increases the number of hydrocarbons that are being released by the engine tends to increase. The main reason for hydrocarbon emissions is due to high ignition delay which is caused by incomplete combustion of the fuel. The hydrocarbon emissions were reduced by 21.5% when the engine is operating with coated piston when compared with the normal piston. When compared to an engine operating with biodiesel the hydrocarbon emissions are lower for B30 blend. It was observed that the concentration of HC decreases with increasing brake power due to complete combustion of the fuel particles. The concentrations of HC emissions for the diesel injected at different injection pressures i.e 210bar, 220bar and 230bar are shown in figure. Compared to fuel injected at 210bar injection pressure, the fuel injected at 220bar and 230bar have lower hydrocarbon emissions. At full load, when compared with fuel injected at 210 bar, hydrocarbon emissions decreased by 16 PPM for B30. There was 23.52% reduction in hydrocarbon emissions observed at 230bar injection pressure when compared to engine operating at an injection pressure of 210bar.



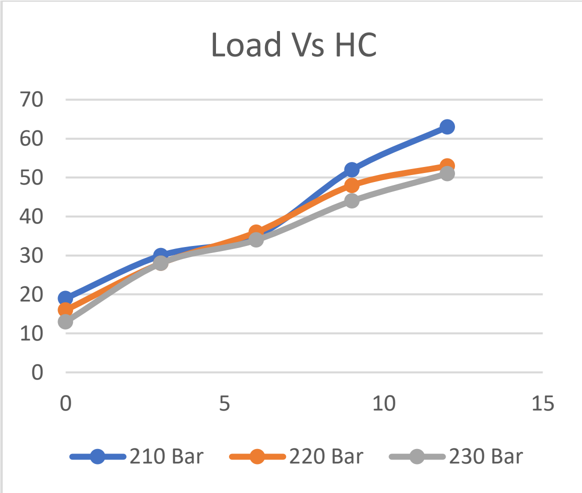


Fig 5 Load Vs HC emissions for various biodiesel blends and injection pressures

5.5 Load Vs Carbon Monoxide (CO)

The variation of carbon monoxide (CO) with load is shown in figure 6. Carbon monoxide is the major emission which is released from internal combustion engines due to the unavailability of oxygen for the fuel particles. The variation of load Vs carbon monoxide is shown in the below figure. From the figure it is evident that as the load increases carbon monoxide emissions tends to increase. There was decrease in carbon monoxide emissions by 4.7% for thermal barrier coated piston when compared to normal piston. Compared to fuel injected at 210bar injection pressure, fuel injected at 220bar and 230bar have lower carbon monoxide emissions. Compared to fuel injected at 210 bar, the fuel injected at 230bar injection pressure has decreased Carbon monoxide emissions. There was 5% reduction in Carbon monoxide emissions observed at 230 bar injection pressure when compared to engine operating at 210 bar.

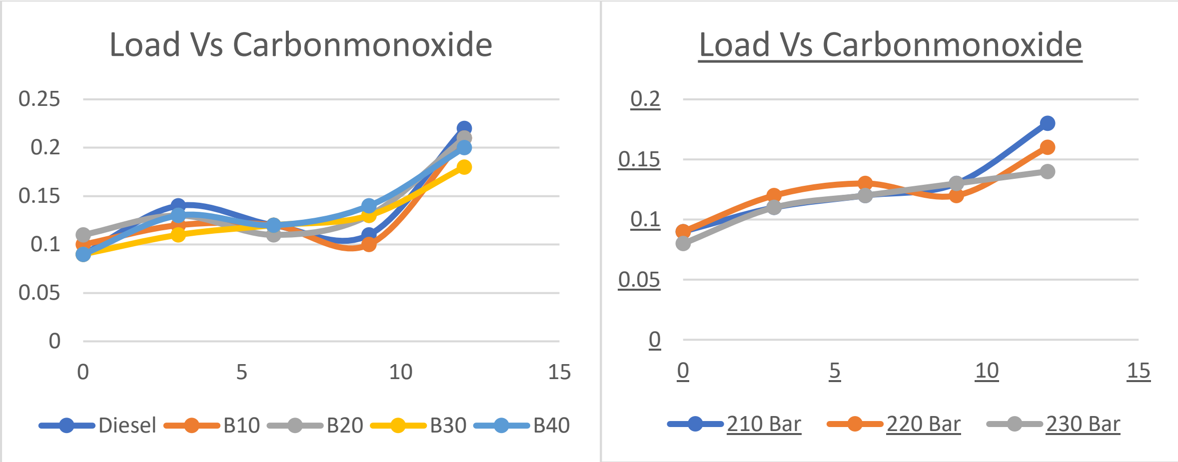


Fig 6 Load Vs CO emissions for various biodiesel blends and injection pressures

5.6 Load Vs Oxides of Nitrogen (Nox)

The variation of Oxides of Nitrogen (Nox) with the load is shown in figure 7. The oxides of nitrogen emissions are caused due to high temperatures in the engine cylinder.The Nox emissions was increased about 5.8% when the engine is operating with thermal barrier piston when compared with normal piston. The plot reveals that as the load increases the number of oxides of nitrogen from the engine increases, for the diesel at full load condition the Nox emissions occurred at 377 PPM and 473 PPM at B40 blend. The amount of Nox emissions increases as the blend percentage increases. The concentrations of NO_x emissions of for the fuel injected at different injection pressures i.e 210bar, 220bar and 230bar. Compared to fuel injected at 210bar injection pressure the fuel injected at 230bar have higher NO_x emissions and diesel injected at 220bar injection pressure have lower NO_x. Compared to fuel injected at 210 bar, the diesel injected at 230bar injection pressure has increased oxides of nitrogen emission of 5.11%.

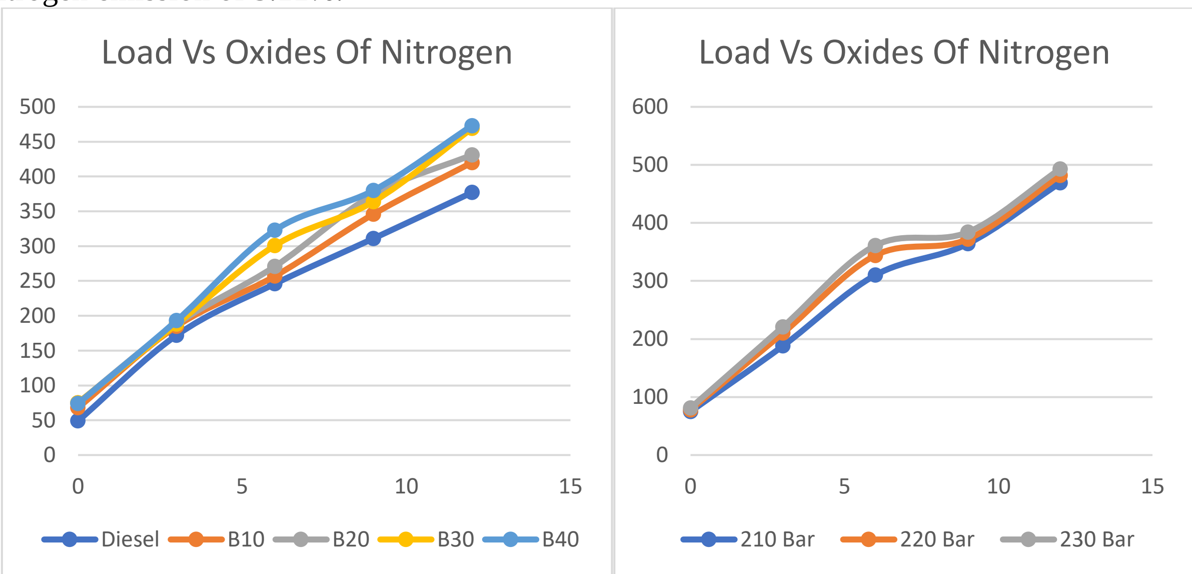


Fig 7

Load Vs NO_x emissions for various biodiesel blends and injection pressures

6. Conclusions

The brake thermal efficiency of the engine was greatly increased by 14.96% for thermal barrier coated piston and the maximum thermal efficiency for biodiesel occurred at 18.11% for B30 blend. As the injection pressure of the engine increases from 210 bar to 220 bar, the brake thermal efficiency was increased by 25.92%. The brake specific fuel consumption of the engine with thermal barrier piston was reduced by 25% when compared to normal piston, and the B.S.F.C was decreased for B30 blend compared to other blends by 21.95%. As the injection pressure of the engine increase there was a great reduction in the brake specific fuel consumption. Brake specific fuel consumption for waste plastic bio diesel blend for increase in injection pressure occurred as 0.41 kg/kWhr at 210 bar, and 0.37 kg/kWhr at 230 bar, which was decreased by 10.81%. The engine emissions like hydrocarbon emissions reduced by 23.52%, carbon monoxide emissions reduced by 5%, and the oxides of nitrogen emissions was reduced by 5.11% when the engine was operating at an injection pressure of 230 bar.

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