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Direct Injection Diesel Engine Performance Improvement and Emission Control using Boost Pressure

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ABSTRACT:
The present investigation is to analyse the influence of boost pressure and injection pressure on combustion process and emissions for various engine loads and speeds. A single cylinder diesel engine that is equipped with a manual direct injection system is considered for the experimental work. Emissions such as HC, NOx and brake specific fuel consumption were monitored using gas analyzer. A turbocharger and dilution tunnel is designed such a way that a boost pressure will be created from the compressor driven turbine using engine exhaust. The compressed air was mixed with the exhaust gas in the dilution tunnel to oxidize the hydrogen and carbon into water vapour and carbon dioxide.

KEYWORDS:
Turbocharger; Boost pressure; Direct injection; Diesel engine; Fuel consumption; Emissions

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1. Introduction

The direct injection (DI) diesel engines are produce efficient power is well known. The diesel engines can be described to the fact that they are much more efficient than petrol engine. However diesel engines rejects about two thirds of the heat energy of the fuel, one third to the coolant, and one third to the exhaust, remaining only about one third of useful power output. Diesel engines exhibit a propensity for high nitrogen oxide (NOx) and particulate matter emissions and most strategies to reduce either NOx or particulate emissions cause an increase in the other emission. The reduction of NOx and emissions from diesel engines has been challenging. Most strategies to reduce either NOx or particulate emissions cause an increase in the other. Also, emissions reduction strategies, especially those that target NOx, often cause an increase in brake specific fuel consumption (BSFC). Thus work to reduce emissions while retaining or improving previous BSFC levels is currently being conducted throughout the industry. Combustion in diesel engines is a complex heterogeneous spray process, which is highly dependent on fuel injection parameters. Therefore, precise control over fuel injection, and thus spray formation, is essential to controlling combustion processes [1-2].

Combustion in diesel engines can be affected substantially by changing the composition and quantity of the intake charge. In results have indicated that use of multiple injections to control the fuel spray formation combined with exhaust gas recirculation and variable boost pressure to control charge composition and quantity can provide substantial simultaneous reductions in emissions of particulate and NOx from DI diesel engines. The variable boosting system is another technology used to gain more control over combustion processes in diesel engines. It is the use of a variable boost pressure system. A variable boost system allows flexible control and thus optimization of boost pressure for different load and speed conditions. In addition to the original power and efficiency goals of variable boost systems. These systems have proven to improve emissions and transient response. Thus variable boost systems are expected to be an important component for low emissions diesel engines [3-7]. The purpose of the dilution tunnel is to adsorption of hydrocarbon in the exhaust. The dilution tunnel is a mixing device that is designed to ensure that the exhaust is thoroughly mixed with dilution air. The dilution air is compressed air from the compressor that is blown into the dilution tunnel, which enhances mixing. This indicates that much of the hydrocarbons and some emissions are adsorbed onto the soot while travelling through the dilution tunnel. If this is true a large portion of the emissions might be eliminated in the dilution tunnel. A portion of diluted exhaust is drawn from exhaust gas analyzer [9].

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Turbines (VGTs) is sequential hydro supercharging (SHS). SHS systems use turbocharger compressor impellers driven by hydraulic turbines. An engine driven hydraulic pump would provide hydraulic power for the hydraulic turbines. The hydraulically driven compressors are used to increase the pressure of air supplied to the engine's normal turbocharger compressor. This type of system would allow very flexible control of boost levels and retain the availability recovery of the turbocharger. Clearly, with the present variety of available variable boost systems, the effects of boost pressure should be studied in more detail. Thus, this work is dedicated to study the effects of boost pressure [10].

When un-waste gated turbocharger is used to provide boost for an engine, a compromise must be made. Midrange torque and efficiency must be sacrificed in order to not over-boost at high loads and speeds. Waste gates allow some exhaust gas to bypass the turbocharger turbine at high loads and speeds thus reducing boost pressure and avoiding an over-boost situation. The drawback to waste gates is that bypassed gas availability is wasted leading to reduced overall efficiency at high loads and speeds. In an attempt to provide increased boost at lower loads and speeds while not over boosting or operating at reduced efficiency at high loads and speeds, variable boosting systems such as VGTs and variable speed superchargers have been developed. There are three types of VGTs, those with variable area turbines, those with variable geometry nozzles, and those with axially movable vanes. One type of VGT that appears especially promising is the axially movable vane turbocharger. They have a high degree of flexibility and fewer moving parts than other designs. The study reveals that variable injection pressure improves the injection strategies and advancing the auto ignition of the engine [11].

2. Experimental setup

A turbocharger is a small radial fan pump driven by the energy of the exhaust gases of an engine. A turbocharger consists of a turbine and a compressor on a shared shaft as shown in Fig. 1. The turbine converts exhaust heat and pressure to rotational force, which is in turn used to drive the compressor. The compressor draws in ambient air and pumps it in to the intake manifold at increased pressure, resulting in a greater mass of air entering the cylinders on each intake stroke as shown in Fig. 2. The objective of a turbocharger is the same as a supercharger, to improve the engine's volumetric efficiency by solving one of its cardinal limitations. A naturally aspirated automobile engine uses only the downward stroke of a piston to create an area of low pressure in order to draw air into the cylinder through the intake valves [5]. The pressure in the atmosphere is no more than 1 atm, so there will be a limit to the pressure difference across the intake valves and thus the amount of airflow entering the combustion chamber. Since the turbocharger increases the pressure at the point when air is entering the cylinder, a greater mass of air will be forced in as the inlet manifold pressure increases. The additional air flow makes it possible to maintain the combustion chamber pressure and fuel/air load even at high engine revolution speeds, increasing the power and torque output of the engine. To avoid detonation and physical damage, the pressure in the cylinder must not go too high and must be controlled by venting excess gas. The control function is performed by a waste gate, which routes some of the exhaust flow away from the turbine. This regulates air pressure in the intake manifold. A simpler alternative is to restrict the input area of the compressor [3].

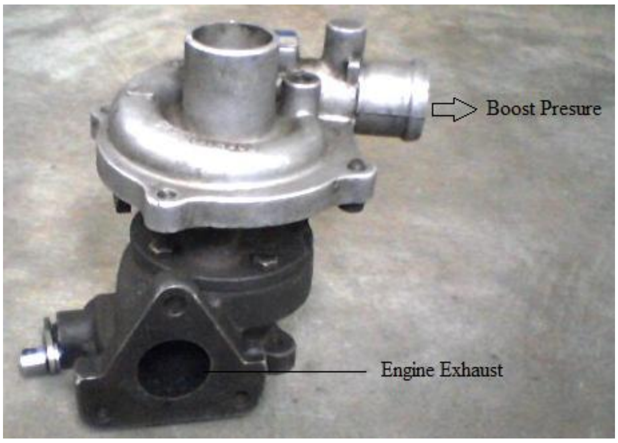

Fig. 1: Designed turbocharger

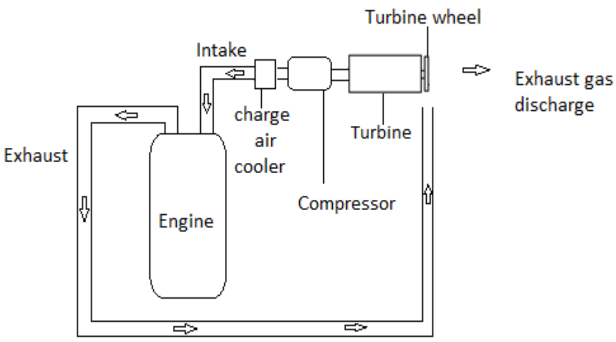

Fig. 2: Booster pressure setup

Single cylinder Kirloskar model water cooled diesel engine as shown in Fig. 3 is used to conduct the experiment. Full specifications for the engine are given in Table 1. A schematic of experimental setup is shown in Fig. 4. The fuel used during the present testing was obtained from a commercial fuel vendor, so it represents a valid sample of what is currently available to the trucking industry. A sample of the fuel was analyzed and the results are given in below. Emissions data recorded during experiments include total hydrocarbons, CO, CO_2 and NOx. Emissions data was obtained using the exhaust gas analyzer.

Table 1: Engine Specification

Specification	Value
Bore and stroke (mm)	87.5 and 110
Compression ratio	17.5: 1
Speed (rpm)	1500
Cubic capacity (litres)	0.661
Method of cooling	water cooled
Fuel timing	27° bTDC
Clearance volume (cc)	37.8
Rated power (kW)	5.2 (7 HP @ 1500 rpm)
No of Strokes	4

Fig. 3: Photographic view of engine

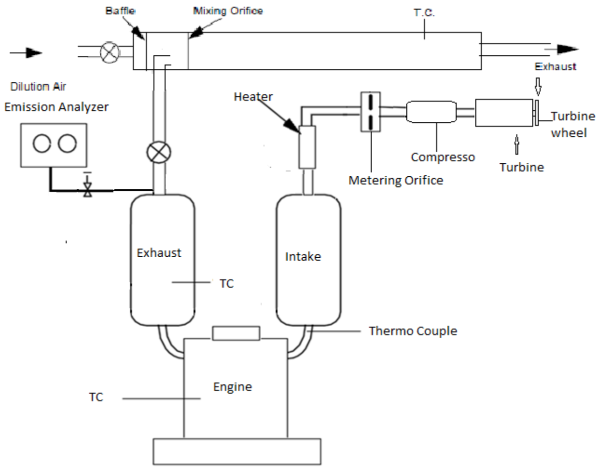

Fig 4: Experimental setup line diagram

3. Results and discussion

Testing was done at six operating conditions that constitute a six-mode operation [8] as follows:

- Mode 1 is a simulation of idle which is an important running condition for DI diesel engines because this type of engine often sees extended idling periods while in operation.
- Mode 2 is a low speed and low load operating condition. Under these conditions, injection occurs when the piston is past TDC. The lower in-cylinder temperature causes a longer ignition delay, and consequently a large premix burn. The large premixed burn, in turn, causes high temperatures late in the cycle. This high temperature improves the soot oxidation but also increases NOx levels.
- Mode 3 is an operating condition of engine load at 4kg. In this mode, the fuel is sprayed for a period of time longer than the ignition delay that lasts well into the diffusion burn. Thus, the heat release displays ignition delay, premixed burn and diffusion burn.
- Mode 4 is an operating condition of engine load at 6kg. In this mode, the engine operates at high load and speed conditions, where normal emissions control schemes are less effective.
- Mode 5 refers the engine operation at 8kg load.
- Mode 6 is a10kg load operating condition. It also depends on the mixing rate with the air during this period in cylinder.

The test conditions such as engine speed, engine load and intake temperature were held constant for all testing at a given mode. One objective of the present study was to explore the emissions and performance characteristics of a current state of the DI diesel engine using the standard injection system. Fig. 5 shows that gradual increase of brake power for an increase in the engine load. Fig. 6 shows at no load condition in engine leads to reduced fuel consumption 0.5 kg/hr. At higher loads, the engine consumes more fuel of 0.9kg/hr to compensate the maximum loading. The brake thermal efficiency increases gradually and gives 18% at maximum volume. Figs. 7 and 8 show the characteristics of fuel consumption for considered six modes of operation. At normal injection of fuel, the fuel atomisation is poor which reduces the combustion flame front propagation speed. In this boost pressure method, the improvement in fuel atomisation leads to better combustion and reduced CO, CO_2, HC and NOx emissions as shown in Figs. 9 and 10. The CO emission is initially at nearly 0.2% at the maximum load condition and then it reduces drastically to zero emission where as HC emission increases. The NOx emission increases to 160 ppm at maximum load due to thermal efficiency of the engine boost pressure.

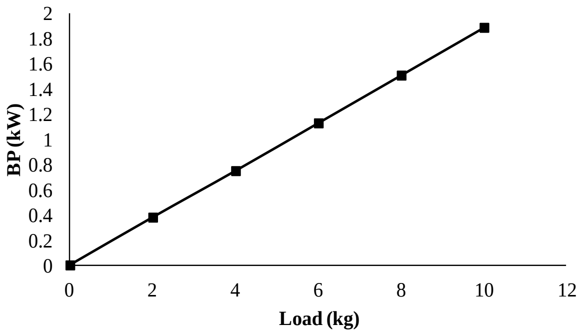

Fig. 5: BP vs. Load

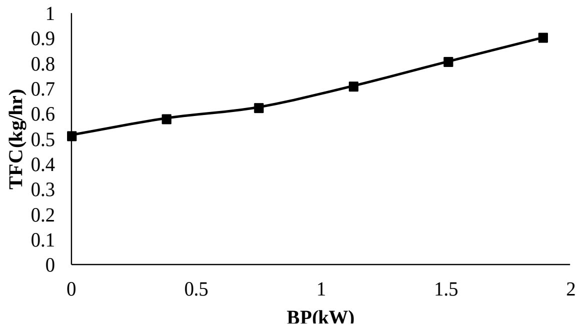

Fig. 6: TFC vs. BP

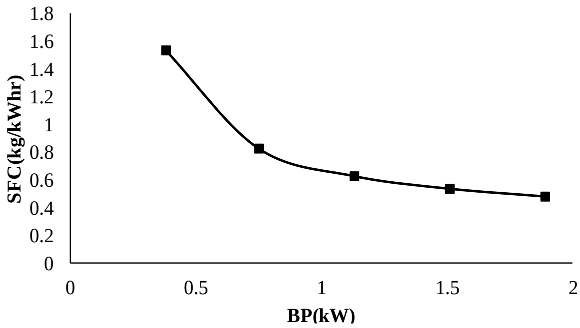

Fig. 7: SFC vs. BP

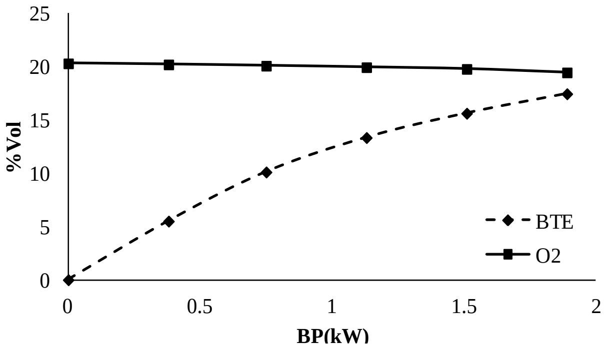

Fig. 8: BTE & O_2 Emissions vs. BP

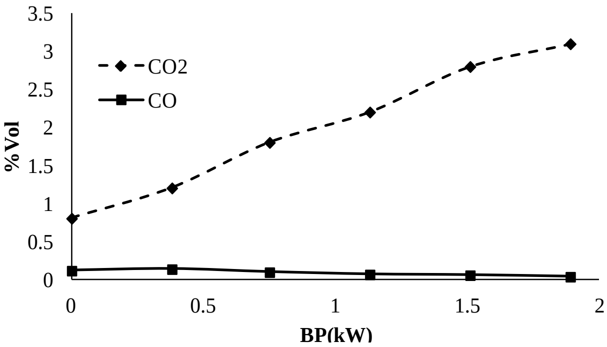

Fig. 9: CO & CO_2 Emissions vs. BP

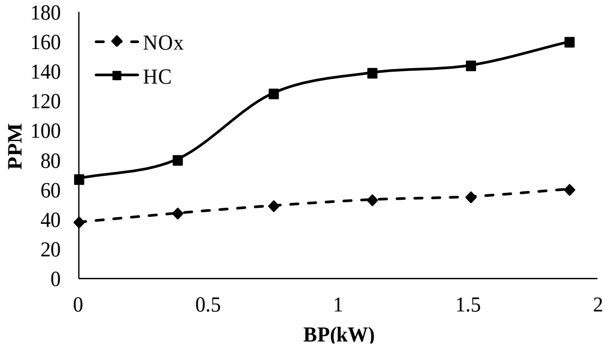

Fig. 10: HC & NOx Emissions vs. BP

4. Conclusions

The performance and emission characteristics of single cylinder engine is measured and analyzed by means of exhaust gas analyzer. From the analysis of results it is inferred that the HC and NOx emission is high when compared to the standards. In order to increase the performance and reduce the emissions at a stretch, a turbocharger and a dilution tunnel is designed. In this boost pressure method, the improvement in fuel atomisation leads to better combustion and reduced CO, CO_2, HC and NOx emissions when compared to normal injection method. As a future work, turbocharger and dilution tunnel design will be optimized.

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