Study on CRDI engine for the various fuel injection pressures

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Abstract: The people in our society are highly depended on petroleum for their activities. The petroleum is a finite source and it produce several problems such as rising carbon dioxide level in the atmosphere. Around 75% of fuel produced is used for as an energy source for transportation, heat and electricity generation. This study was carried out to understand the effect of fuel injection pressure on the CRDI engine for the performance, combustion and emissions. This work has been done out on a four stroke, single cylinder diesel engine. The fuel injection pressure was varied from 400 bar, 500 bar and 600 bar by having the fuel injection angle as 20°bTDC. The collected data were analysed for various parameters such as brake specific fuel consumption (BSFC), brake thermal efficiency (BTE), CO, CO\textsubscript{2}, HC, NO\textsubscript{x} and Smoke emissions for diesel fuel. CO, HC and smoke emissions were reduced by increasing the fuel injection pressure. NO and CO\textsubscript{2} emissions were increasing by increasing the fuel injection pressure. This is due to injected fuel droplets find smaller as the injection pressure increase, which leads to improve atomization of the fuel. The BTE and SFC were not much varying.

Keywords: CRDI, Injection Pressures, Diesel, Emissions, Performance

1. Introduction

CRDI engine can take higher pressure up to 2000 bar of fuel through rail solenoid valve, which is oppose to the less pressure of normal fuel pump. If there is high pressure apply on the injection it produce the power and the lower pressure is applied on the injection process by injecting the small droplets of fuel it get the benefits of fuel consumption, due to this small droplets it gives ratio of surface area to volume. Because of this complete combustion get happen by the proper air fuel mixture in the combustion chamber and the vaporized part from the surface of droplet \cite{1}. The most modern fuel engine system which is known as CRDI engine and it also called Common rail direct injection engine. In this we are using the diesel fuel for completing the study and this diesel fuel get supply forwarded to the fuel injectors and all diesel engine manufactures use the CRDI technology on comparison to petrol engine it has gasoline direct injection. The design and the working principle of this two type of technology is very much same it consist of fuel rail and then fuel further supplies to the fuel injector. Their parameters are different from each other such as pressure and different type of fuel, blended fuel get use in this technology. In this CRDI system the
combustion happened in the combustion chamber which get seen into the cavity of piston from TDC to BDC. Now a days the sum is solving of conventional diesel engines by this CRDI technology. These engines fitted in the passenger vehicles gives greater performance and lessen noise of the engine [2]. The working principle of this engine is governed by engine control unit which inject the fuel in injectors mechanically and electrically. The CRDI engines are connected to the fuel injector by separate pipes and the diesel fuel is stored in cylinder at various pressure it makes the common rail to all injectors. Fuel pump control the timing of fuel injection, during this work very much amount of fuel get injected. This fuel pump is working parallelly with fuel injectors and the pressure is controlled by fuel pump. The fuel get directly injected into the combustion chamber this is one of an advantage of CRDI engine. In older engines the indirect injection system get used in this fuel injected into the pre-combustion chamber after that fuel get enter into the main combustion chamber. In CRDI engine the fuel get pressurised by the help of high pressure pump supply. This pressure pump compress fuel at various pressure of one thousand bar or about 15000 psi it then supply the fuel by higher pressure pump. The fuel get scattered at separate fuel injectors then this injectors inject the fuel to the combustion chamber. The CRDI engine having injector system which is connected to the turbo charger it increases the power and done the emission standard. It improve the engine performance and power of engine, it also control the emission, fuel efficiency, throttle response. If the design get change it not be affected on the working principle and technology. The engine performance in mainly depends on the design of combustion chamber , type of injectors which injects the fuel and different pressure fuel.

The influence of injection parameter like injection pressure and injection duration on performance and emission of common rail direct injection system assisted diesel engine has been evaluated using central composite design (CCD). They observed the brake thermal efficiency was improved and the fuel consumption reduced due to better atomization [3]. High fuel and pilot injection pressures simultaneously reduces NOx 35% and smoke 60 to 80% without adversely affecting fuel economy. They concluded that reduction in ignition delay does not lead to effective improvement at usual injection timings before TDC. However, when the injection timing is considerably retarded or when the original ignition delay is relatively long, shortening of the ignition delay is effective in reducing premixed combustion, therefore the NOx emissions reduce. In the CRDI system, post-injection or secondary injection occurs after the main injection, while the combustion process is still on. Using post injection, soot particles are re-ignited and this reduces soot emissions by 20 to 70% [4]. Unwanted plastic pyrolysed fuel mixture was tested in CRDI system with many injection pressures. They found 600 bar pressure provides improved brake thermal efficiency at full load settings for 15PDB fuel mixture [5]. Diesel-tung oil-ethanol fuel mixture was tested with various injection types in the CRDI system. They found combustion period got reduced, combustion pressure and HRR got increased. Performance got increased [6].

2. Experimentation

This experiment is related to CRDI engine in that diesel fuel get used. While injecting the fuel it was observed for the combustion process, performance of CRDI engine, emission process at various pressure. The compression ratio is about 17.5:1 and it produced up to 25% more torque at rated power 3.5 kW compared to others engine. The experimentation were connected on four stroke single cylinder diesel engine. The process has been done at various fuel injection pressure from 400 bar, 500 bar and 600bar. And used fuel injection angle as 20 degree b TDC. The collected data ware analysed at various parameter such as BTE, CO, CO₂, HC, NOₓ & Smoke emissions for diesel fuel. The pressure pump provide high pressure fuel to the common rail. Common rail store the fuel and maintained a constant pressure in the common rail line. This pressure is constantly available at injector. The injection pressure is independent of the engine speed. The amount of fuel injected in the burning chamber is controlled by actuating solenoid valve in the injector. As solenoid is energized, injection begins. Injection pulse width, multiple injection and duration of injection all are controlled by ECU of CRDI system. The system pressure was controlled by mean of a pressure sensor. The figure 1 shows the ECU controlled CRDI system. First the sensor of the system are used to give the input to ECU. The injector get signal from the ECU on the basis of engine speed
and temperature which is engine factor. This sensor control all the various component of engine. It required that much quantity of fuel in required time duration which then calculated by it. Major components includes - fuel injector, common rail, high pressure fuel pump, ECM/ECU, pressure sensor, rail pressure limiter. For this investigation the test engine used which have persistent speed, mono cylinder, 4 stroke, water cooled CI engine of Kirlosker, DM-10, which was connected to an AC alternator on which we had applied load on it. Diesel fuel is use to run the CRDI engine to observed the emission concentration of the gases in atmosphere at various injection pressure. The speed of this engine is 1500 rpm. Before starting the engine enough quantity of lubricant get added into the sump. This engine is connected to the fuel tank, dynamometer and the equipment which can used to measured the performance, combustion and emission reading.

While the emission take place many gases get emitted from the engine to the atmosphere at this time gas analyser is used to measure and detect the quantity of gas from mixture of the other gases. Gas analyser is used in many industries, factories, for agriculture purposes to measure the gas percentage which get emitted in the atmosphere. The smoke emitted by a diesel engine of cars, buses, trucks, all diesel vehicle, locomotives and large stacks which is from industrial operations in which the amount of light get blocked, it measured and detect by the smoke meter it also referred as opacity meter. This smoke meter read out the display smoke density which measures the efficiency of combustion. Due to this the smoke meter is a sterling tool which used to maintain the diesel engine for enhancing the fuel economy and protection of the environment. The optical properties of diesel exhaust is measured by the instrument which is known as smoke opacity, figure 2. The visible black smoke emission utilizing such as physical phenomenon by scattering and absorption which extinct the light beam and this qualified by the smoke opacity instrument.

![Photographic view of CRDI engine](image-url)
3. Result and Discussion

The test is conducted on single cylinder engine at different pressure ranging from 400 bar to 600 bar with the interval of 100 bar i.e., 400 bar, 500 bar, 600 bar. At each injection pressure, load on engine increased from 0 to 12 kg with the interval of 3 kg and readings of performance and emission were recorded. It found that performance was slightly increased by increasing the injection pressure. As load and pressure increase brake thermal efficiency increase and specific fuel consumption decreases. In the case of emission it shows large decrease with change in injection pressure. The performance of an engine are analysed by the fuel consumption, and it plays a very important role in this. It shows that the amount of fuel consumption get reduce while the injection pressure get increases. The fuel particle diameter get reduce due to increasing in injection pressure. And because of this reason better consumption and atomization get occurs properly.

![Figure 2. Photographic view of Exhaust Gas Analyser](image)

![Figure 3. BTE vs Brake power](image)
The figure 3 shows that the BTE is better while increasing the pressure. And this pressure is from 400 bar, 500 bar, 600 bar. The BTE get better at the pressure get increases than the standard pressure. The brake thermal efficiency get increases up to maxima and then slightly decreases for all the SOI timing at 20° bottom dead centre SOI timing. When the applied load get increases the BTE get increases. Brake thermal efficiency is lesser for the 400 bar pressure and get slightly increases for the 500 bar 600 bar.

It is the main part of the experiment it also important in engine design because it affect to the emission of gases and the performance of engine, characteristic such as noise, vibration, and durability. This combustion is get performed on 400, 500 and 600 bar pressure at 0%, 25%, 50%, 75% and 100% load which was applied on the engine. While performing on this load and this pressure, got the combustion data and after analysing combustion data the graph get obtain at all three pressures. The figure 4, 5 & 6 shows the pressure vs crank angle at different load and at different SOI timing which can see in the figure. It shows at different load at various crank angle and SOI timing the cycle pressure is at the peak in the cylinder. The peak in-cylinder pressure is above the 50 bar for 0% load, above 60 bar for 25% load, above 65 bar for 50% load, at 71 bar for 75% of load and above 74 bar is for 100% of load.

Oxidise the nitrogen in the air is due to high temperature combustion of fuel where the temperature is very hot this reason cause the emission of NOx. In this the hydrogen get burn at very high temperature. If the concentration of oxygen is more the NOx emission is more is fully depend on the concentration of the oxygen and at high cylinder temperature [7]. This figure 6 shows the increase in NOx emission. In this the NOx emission get increases while increasing pressure and the emission get also increases while increasing the load on the engine. NOx emission get increase up to 2235 ppm while increasing the load up to 3.5kW and pressure up to 600 bar.
Figure 5. Pressure vs Crank Angle (at 500 bar)

Figure 6. Pressure vs Crank Angle (at 600 bar)
The incomplete fuel combustion in the burning chamber and little bit combustion of lubricating oil in gone to the chamber because of piston and the dynamics of ring this causes the emission of HC gas [8]. The learner air fuel mixture and the richer are the main reason of hydrocarbon emissions. Variation in HC emission at various SOI timing for varying engine load are shown in graph. From the figure 4. load vs HC shows that while increase the injection pressure it increase atomization rapidly due to this the combustion of fuel happen better. It shows that while increasing the load HC emission also get increases. While increasing the pressure at 400 bar 500 bar 600 bar the emission on HC get decreases.
The incomplete combustion of hydrocarbon cause the CO emission and it is mid product of combustion. The CO emission are affected by the chemical reaction in the chamber which got happen due to incomplete combustion [9]. Figure 5 shows the CO emission at various engine load at different fuel injection timing. It shows the Brake power vs CO emission it clear that while increase in pressure it decrease the emission percentage of CO. Carbon monoxide is produce from the oxidation of compound containing carbon and it is resulted due to incomplete burning. From this figure it clear that while increasing the load the CO emission get increases and while increasing the pressure the CO emission get increase and sharply increase towards the full load.

**Figure 9.** CO emission

**Figure 10.** CO₂ emission
The emission of Carbon Dioxide gets increased while increasing the both pressure from 400 bar, 500 bar, 600 bar and the load from 0 to 3.5kW. At 0kg load the emission of Carbon Dioxide is at 1.42% on 400 bar and get slightly increase on 500 bar and 600 bar up to 1.79%. And at the load of 3.5kW the emission of CO₂ can see the more difference in the emission percentage up to 6.88 and it get slightly increases when the pressure get increases on 500 bar and 600 bar, figure 10.

Owing to the mingling of air fuel mixture the injection pressure of fuel get increase and its get better at ignition period it completes the combustion [11]. Therefore when the injection pressure get increase then smoke emission get decrease. The figure 8 shown that while increasing the load the emission of Smoke get increases but while increasing the pressure emission of smoke get decreases. At 0 kg load the smoke emission is very less as shown in the figure the emission percentage on 0 kg load is 7.9% and it not much get increase while increasing the pressure on 400 bar the emission percentage is 7.9, on 500 bar 7.505 and on 600 bar it get slightly get decrease.

4. Conclusion

- From this study, we found that while increasing load as well as injection pressure the brake thermal efficiency get increases.
- When the injection pressure get changes from 400 bar to 600 bar it observed the large variation in the case of emission.
- NO emission increases with increase in pressure from 400 to 600 bar owing to higher combustion temperature.
- The emission percentage of CO₂ get increases while increasing the injection from 400 bar, 500 bar to 600 bar and while increasing the load.
- CO, HC and Smoke density decreases while the injection pressure increases from 400 to 600 bar pressure.
- Overall it is clear that, it enhance the engine performance and reduce the emission of few gases which get emitted in the atmosphere.
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