Performance of CI Engine Using Swirl Type Retrofit

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Abstract. Due to its higher thermal efficiency diesel engines are used worldwide in transportation, agriculture and many. The problem associated with these diesel engines are less efficiency and release of toxic emissions like CO, HC and NOx to the atmosphere. These problems can be overcome by use of alternative fuels and by engine modification. Modification of fuel spray is one of the methods to achieve complete combustion of fuel, which helps in achieving higher efficiency and reduced toxic emissions. This work is carried out by using an attachment for fuel injector known as retrofit. Experiments were conducted using retrofit attached to fuel injector nozzle and found to be increased in efficiency of the engine and reduced toxic emissions when compared with conventional injector without retrofit.

1. Introduction

People are searching for engines that emit less harmful emissions into the environment due to increased pollution and a drop in oxygen levels, which affects all living beings. To stop all of this, the Government of India has implemented major changes, one of which is that instead of using BS V standards, BS-IV standards are recommended. Many researchers are working to improve the CI engine's performance and reduce toxic emissions. The effects of these toxic emissions reached villages as well, having a negative effect on the agricultural sector. To reduce such toxic emissions, create an engine with less exhaust, which can be accomplished by achieving complete combustion. One of the parameters that contributes to full combustion is fuel injection.

Ergenc et al., [1] with his experimental work claimed that the efficiency of combustion depends mostly on mixture of air and fuel. They concluded that the formation of this mixture depends largely on the parameters of the injection. They also calculated the optimal timing of the injection of DI diesel engines. A single-cylinder diesel engine has been used to power the pump. In their research, diesel and diesel-esters were used. The rate at which the injection pressure increases has been found to increase with ester mixtures. Zhu Jianjun [2] experimental work has been conducted on a diesel engine. The experiments were carried out using various angles of advance of the injection port and injection pressure. They confirmed that the NOx levels had been reduced in both cases. Researchers have found that there is an effect on particulate matter. Although no significant impacts on CO or HC have been observed.
Nwafor et al., [3] Their research focuses on diesel engines. They did a report on the timing of injections. The same tests were carried out on diesel and vegetable oils to obtain results. The engine stated that it would produce a smoother response at lower loads. The researchers also found that it was more necessary to reduce the ignition delay. At last, they might consider an improvement in injection for both oils. Cenk Sayin et al., [4] Tests were carried out on a diesel engine using ethanol blended gasoline. Tests were conducted at different injection times, which fell within the starter to the intermediate range of timing of injections. In both cases, ethanol was combined with diesel fuel up to a limit of 15%. They found the following by their experiment: In the case of delayed injection timings, NOx, CO2 increased and BTE, CO and HC declined, in the case of advanced injection timings, NOx, CO2 increased and CO, HC reduced with respect to BSFC and BTE, better results were reported at the initial injection timing.

Nwafor [5] experiments have been performed on diesel engines using natural gas. In this research, the timing of injections was progressed and its results were observed. Due to this, a change in the ignition delay was observed. They suggested an acceptable timing of injection during which the engine could run smoothly. They also reported increased fuel consumption at peak load. Kouremenos, et al., [6] The experimental and theoretical investigations were performed on the DI diesel engine. Injection advancement was considered to be a major problem in the study of its effect on combustion and emissions. In contrast, EGR technology has been put in place to regulate pollution levels. A fair rise in peak pressure with sufficient levels of NOx were obtained from the report.

Jesus Benajes et al., [7] Examined combustion changes and combustion products during the pre-and post-injection phase. Single cylinder diesel engines were studied. In this controlled experiment, the rate of fuel injection was varied in order to better understand its effects on combustion and emissions of NOx and soot. The main points their research is that. (i) a pre-injection strategy: a reduction of NOx with a penalty of NOx as well as soot, and (ii) a post-injection strategy: a reduction in soot with a penalty of NOx. Hassan et al., [8] Work has been performed on the impact of injection on the engine. A supercharged diesel engine has been used and tested in many ways. The paper examined engine performance and vehicle emissions. During all the tests, the injection pressure remained constant. However, the variation in the flow rate of the producer gas and the size of the air volume was manipulated. The test was carried out at various speeds, subject to various load rates. The team has finally confirmed that total CO emissions, energy consumption & thermal efficiency of the engine have been reduced.

Hassan et al., [9] The performance and emissions of the engine has been systematically investigated. They also tested the use of vegetable oil portions in diesel and gas blends. Air and/or gas are combined with the air in the intake box. Pilot fuel injection timing has been advanced. Experiments were conducted for different parameters, including the concentration of fuel, speed and weight. It was determined that the engine would operate better with vegetable oil than the producer gas. Emissions are observed to increase at the rated load. They suggested the use of vegetable oil as an alternative energy source for a double-fuelled supercharged gas producer. Gorji et al., [10] The emission characteristics of the diesel engine has been evaluated. The study focuses on injection routes and considerations of amount of injection. Those are the screening requirements used by the Committee. (i) spray cone angle, (ii) timing of injection and (iii) temperature of injection and (iv) multiple injections. Trends in these areas have been substantially different from the events considered. The raise in the injection angle increased the NO formation but lowered the Soot levels.

2. Design of Retrofit

Retrofit is an attachment used with conventional fuel injector. The purpose of using retrofit is to atomize diesel fuel injection. Impeller blade type design has been designed using solid edge software. Using lathe operation and wire cutting D2 tool steel material given shape of the designed retrofit.
Table 1: Mechanical and Physical Properties of D2 Tool Steel

| Mechanical Properties       | Metric               |
|-----------------------------|----------------------|
| Hardness, Rockwell C        | 62                   |
| Hardness, Vickers           | 748                  |
| Izod impact unnotched       | 77 J                 |
| Poisson’s Ratio             | 0.27 – 0.30          |
| Elastic modulus             | 190 – 210 GPa        |

| Physical Properties         | Metric               |
|-----------------------------|----------------------|
| Density                     | 7.7 x 1000 Kg/m³     |
| Melting Point               | 1421 °C              |

Figure 1. Three-hole fuel injector nozzle.

Figure 1 shows CAD model of conventional 3-hole fuel injector nozzle. Nozzle diameter having 9mm is reduced to 7mm using lathe turning operation in order to fit the designed retrofit. Figure 2 and figure 3 shows the CAD model and working model of retrofit respectively.
3. Experimental Setup

![Kirloskar TV-1 Engine Setup](image)

**Figure 4.** Kirloskar TV-1 Engine Setup

**Table 2.** Shows Kirloskar TV-1 Engine specifications

| Engine Details | Performance Parameters |
|----------------|------------------------|
| Diesel Engine | Orifice Diameter (mm): 20.00 |
| Power 3.50 kW | Orifice Co-eff. Of Discharge: 0.60 |
| 1500 rpm      | Dynamometer Arm Length (mm): 185 |
| Single Cylinder| Fuel Pipe diameter (mm): 12.40, |
| Four stroke   | Ambient Temp. (Deg C): 27 |
| Constant Speed| Pulses Per revolution: 360 |
| Water Cooled  | Fuel Type: Diesel |
| Cylinder Bore 87.50(mm), Stroke | Fuel Density (Kg/m³): 830 |
| Length 110.00(mm), Connecting Rod length 234.00(mm) | Calorific Value of Fuel (kj/kg): 42000 |
| Compression Ratio 18.00, Swept volume 661.45 (cc) |
4. Results and Discussion

![Variations of BTHE in %](image1)

**Figure 5.** Shows variations of BTHE with load

Figure 5 shows variation of break thermal efficiency at different loading condition for with and without retrofit models. From the graph it is clear that BTHE increased by 1.8% for retrofit model when compared to without retrofit model. Use of retrofit leads to atomization of fuel droplets [11] leading to more improved combustion. This resulted in increased break thermal efficiency.

![Variations of CO in %](image2)

**Figure 6.** Shows variations of CO with load

Figure 6 shows variation of carbon monoxide at different loading condition for with and without retrofit models. From the graph it is clear that CO emission reduced by 20% for retrofit model when
compared to without retrofit model. Use of retrofit leads to atomization of fuel droplets leading to more improved combustion. Since more complete combustion takes place, it resulted in reduced CO emission.

Figure 7. Shows variations of HC with load

Figure 7 shows variation of unburnt hydrocarbon at different loading condition for with and without retrofit models. From the graph it is clear that HC emission increased by 43% for retrofit model when compared to without retrofit model. Retrofit with impeller blade design used as attachment to the nozzle showed improved combustion but at higher loads carbon deposition took place on the fins of retrofit and this resulted in increased HC emission.

Figure 8. Shows variations of NO with load
Figure 8 shows variation of oxides of nitrogen at different loading condition for with and without retrofit models. From the graph it is clear that NOx emission decreased by 4.5% for retrofit model when compared to without retrofit model. Use of retrofit leads to atomization of fuel droplets leading to more improved combustion. Since more complete combustion takes place, it resulted in reduced NOx emission.

![Variations of Smoke Opacity in %](image)

**Figure 9.** Shows variations of Smoke Opacity with load

Figure 9 shows variation of smoke opacity at different loading condition for with and without retrofit models. From the graph it is clear that smoke opacity decreased by 69% for retrofit model when compared to without retrofit model. Use of retrofit leads to atomization of fuel droplets leading to more improved combustion. Since more complete combustion takes place, it resulted in reduced smoke opacity.

5. Conclusions

From the experimental work it is concluded that use of retrofit as a attachment to the conventional injector nozzle without any modifications in the engine setup lead to improved fuel atomization which resulted in improved performance and decrease in toxic emissions.

- BTHE increased by 1.8% for retrofit model when compared to without retrofit model.
- CO emission reduced by 20% for retrofit model when compared to without retrofit model.
- HC emission increased by 43% for retrofit model when compared to without retrofit model.
- NOx emission reduced by 4.5% for retrofit model when compared to without retrofit model.
- Smoke Opacity reduced by 69% for retrofit model when compared to without retrofit model.
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