Effect of Fuel Intake Temperature on Performance and Emission of Diesel Engine

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Abstract - Heating diesel fuel before injecting into the engine cylinder is the technique employed in this experiment with the primary objective of improving combustion and decreasing emission. This results in gasification of diesel when injected into the engine cylinder leading to better mixing, evaporation and combustion of diesel fuel. This also results in decrease of physical delay period. Experiments are done at standard injection timing with preheating done in the interval of 100°C, 175°C and 250°C. At each temperature, readings are taken at no load, 25%, 50% and 75% of full load. It is observed that preheating results in decreased emission of CO and HC at all the loads. At 50% and 75% load CO and HC decreased by about 35% and 50% respectively. NOx is also increased showing that combustion of diesel fuel is improved. Maximum brake thermal efficiency (BTE) and minimum brake specific fuel consumption (BSFC) is obtained at preheating temperature of 100°C at 75% load condition. With increase in load condition, performance is found to be better at higher preheating temperature. With increase in preheating temperature, performance and emission is better and efficient. Performance improvement is better at 50% load than at no load and 25% load.

1. Introduction
Automotive sector is experiencing disruption due to the emerging technologies like electric vehicle and fuel cell vehicle resulting in the gradual phase out of engine powered vehicle in the near future. But the amount of research going on in the field of IC engine and also well-established infrastructure in terms of fuel refilling stations makes very difficult to neglect its role in automobile. Also the progress in the reduction of emissions and increase in fuel efficiency of IC engines makes it still a favourable option for passenger vehicle. Therefore in this present experimental work, effort is made to reduce the emission and fuel consumption of a diesel engine by heating the neat diesel fuel before injecting into the combustion chamber. This temperature ranges from 40°C to 300°C which increases the chances of fuel getting into gasified ranges producing a homogeneous mixture of air and fuel which will lead towards improved combustion of the fuel. Therefore it is expected that through a detailed study of injecting fuel at different temperatures and measuring the performance of the engine conclusions may be drawn.

Several literatures studied in this regard shows that preheating of fuel is commonly employed in biodiesel applications to reduce viscosity. Other applications is the recently developing Homogeneous Charge Compression Ignition engines. Vijayeshwar [1] explains about diesel vapor combustion system, where diesel fuel in vapour form is introduced in a petrol engine using hot air vaporization techniques. Here hot air is supplied at the bottom of a diesel sub tank resulting in air bubbles which extract diesel
fumes from liquid fuel forming diesel vapors. In this paper, author has not explained about the performance study when using this concept.

Avinash kumar Agarwal et al. [2] studied about exhaust particulates from diesel fuelled Homogenous Charge Compression Ignition (HCCI) engine using diesel vaporizer technology. Diesel is less volatile and has more viscosity compared to gasoline. Hence this technology helps in producing more homogeneous mixture of fuel and air. It consists of a chamber where diesel is injected to an air stream which is electrically heated and also uses heat from exhaust gases to achieve diesel vaporization. Temperature of heating was found to be around 160°C. Engine was run with 0%, 15% and 30% EGR in HCCI mode and performance and emission was compared with normal diesel mode. Results showed that performance were equal with normal diesel mode but NOx and PM found to reduce drastically in HCCI mode. HC and CO showed increased trend due to lower in-cylinder temperature due to leaner mixture and also due to trapping of homogeneous air-fuel mixture in crevice volume and dead volumes in combustion chamber. Another work in the reference [3] showed that preheating inlet air was done to improve the performance of diesel engine with ethanol emulsion. Here air is preheated to 30°C, 40°C and 50°C. From the experiment, it is observed that there is reduction in smoke density, particulate matter and exhaust gas temperature with an increase of nitrogen oxides (NOx) and brake thermal efficiency.

In the series of experiments [4, 5, and 6], vegetable oils like Waste cooking oil, raw rapeseed oil etc were blended with diesel in different proportions with preheating up to a temperature of 135°C showed improved performance and reduction in emissions. A patent works [7] shows a diesel pre-heater is developed using heat from engine coolant without any description on the performance results. Also, there are several pre-heaters [8] available in market which claim that by preheating diesel using engine coolant or by some other methods, fuel efficiency increases by 20 – 30%. A fuel preheater for use with internal combustion engines is disclosed [9]. The preheater works on the principle that by preheating the fuel, the fuel is more effectively vaporized, resulting in more efficient combustion. This preheating is accomplished using heat normally wasted via the radiator. The preheater has a housing, through which heated engine coolant on its way from the engine block to the radiator is routed. A coiled steel gas line is routed through the housing, and is connected between the regular fuel line and the engine. Test results show that there is 40% to 50% of fuel saved with preheating compared to without preheating condition in a 2.5 litre diesel engine.

Most important work related to this experiment is known as Flash Boiling Injection concept [10]. It proposes a new method of utilizing the flash boiling injection effect of high temperature diesel fuel to improve the fuel-spray evaporation and mixing in homogeneous charge compression ignition (HCCI) diesel engines. The combustion and exhaust emissions of the HCCI diesel engine were tested by increasing the fuel temperature to 160 – 200 °C., and the effect of high-temperature flash boiling was clearly demonstrated by the test results. Benefits includes reduction in droplet size by about 50% at 200°C, reduced BSFC and reduction in NOx. But above 150°C of fuel temperature, BSFC, CO and HC emissions increased due to possibly due to reduced spray penetration and extremely short ignition delay. Also under high load condition and high diesel fuel temperature, it is observed that there is excessive injection retard and relative lack of oxygen leading to deterioration of the late combustion and finally result in increased fuel consumption.

2. EXPERIMENTAL SETUP

The performance characteristics were carried out on variable compression diesel engine. The specifications of the engine are as stated as below. A four-stroke single cylinder, water cooled diesel engine is used for the experiment and specification is provided in table.1

Figure 1 shows the schematic arrangement of a diesel engine test rig used for the experimentation purpose. A rope brake type dynamometer is used for loading the engine. Heating of the fuel is done using a electric heater installed on the fuel line between the fuel pump and injector. Full load of the engine was found to be 16 kg (based on rated power and considering brake drum radius of 0.15m). During experiment engine was loaded with 0%, 25%, 50% and 75% of full load. Due to safety reasons and engine condition, engine load was limited to 75% of full load (12 kg). At each loading, fuel temperature varied from room temperature (normal diesel) to 250°C at the interval of 100°C and 175°C.

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Fuel temperature was controlled manually with the help of thermocouple arrangements. Standard injection timing was found to be 23° before TDC and experiments conducted with variable injection timing is not reported here.

| Sl. No | Name              | Details          | Sl. No | Name              | Details          |
|--------|-------------------|------------------|--------|-------------------|------------------|
| 1      | No. of cylinder   | 1                | 7      | Compression ratio | 16.5:1           |
| 2      | No. of stroke     | 4                | 8      | Brake drum diameter | 275mm           |
| 3      | Fuel              | Diesel           | 9      | Rope diameter     | 19mm             |
| 4      | Rated power       | 3.7 kw@1500 rpm  | 10     | $C_D$ of orifice  | 0.65             |
| 5      | Cylindrical Diameter | 87.5mm         | 11     | Orifice diameter  | 19mm             |
| 6      | Stroke length     | 110mm            |        |                   |                  |

Figure 1. Schematic arrangement of Diesel Engine Test Rig with Pre heater

Figure 2. Heater arrangement in the fuel pipe line

Figure 2 shows the heater arrangement in the diesel engine setup. Electric heater of 750 W capacity was used to heat the fuel by mounting it on the fuel pipe line which connects the fuel pump to the injector or
nozzle. Since the fuel is flowing in a closed pipeline it can be heated above the flash or fire point of the diesel. Also heating the fuel in the location between pump and nozzle [10], will not disturb working of the pump and pumping capacity.

3. RESULTS AND DISCUSSION

3.1 Performance and Emission at 75% load condition:
Figure 3, 4 and 5 shows variation of Brake Power (BP), BSFC, and BTE for pure diesel at 75% load condition. Compared to room temperature, these parameters remained almost constant at higher temperatures. BSFC reduced by 1.65% at 100°C and brake thermal efficiency increased by 0.34%. As the fuel is heated, vaporization increases and physical delay period should reduce. This will affect the peak pressure rise and heat release rate. Since in this experiment, injection timing is fixed at 23° before Top Dead Centre (TDC), there is no appreciable improvement is observed. It is also found in literature [10], as the fuel temperature is increased, it affects the spray penetration and shortens ignition delay.

Figure 6, 7 and 8 shows NOx, HC, and CO emissions with temperature. It is observed that with increase in temperature HC decreases. NOx and CO initially increases but decreases after 100°C. The minimum value of CO and HC is at temperature of 250°C and is decreased by 37.5% and 56% respectively. It proves that the heating of fuel improves mixing of fuel and air, increases homogeneity and improves combustion. In case of NOx emission, initially it is increased by 42% and then decreases. This shows that mixture is tending to become homogeneous and lean resulting in decrease in NOx at higher temperature. Hence it can be concluded that preheating has a great benefit on reducing emissions.

![Figure 3. BP variation with fuel temperature](image1)

![Figure 4. BSFC variation with fuel temperature](image2)

![Figure 5. BTE variation with fuel temperature](image3)

![Figure 6. CO variation with fuel temperature](image4)
3.2 Performance and Emission at 50% load condition:

Figure 9, 10 and 11 shows variation of BP, BSFC, and BTE for diesel at 50% load condition. Compared to 75% load, 50% load shows better performance improvement. The maximum value of BP is at temperature of 100°C which increases by 1.01% and the minimum value of BSFC is at a temperature of 175°C and is found to decrease by 7.41%. Maximum value of brake thermal efficiency is at 175°C which increases by 1.45%. This shows that preheating leads to increase in evaporation and mixing of fuel with air leading to better combustion. It also proves that engine load also affects the mixture formation, spray penetration and combustion ability of fuel air mixture. Also literature shows that, at higher load and fuel temperature, injection is retarded and affects late combustion leading to decrease in performance. Hence performance at 50% load is better than 75% load.
Figure 12, 13 and 14 shows HC, NOx and CO emissions with temperature. It is observed that with increase in temperature HC and CO decreases, but NOx increases. At room temperature, CO is 0.13, HC is 51 and NOx is 88. The minimum value of CO is at temperature of 250°C and is decreased by 38% and the minimum value of HC is at a temperature of 175°C which decreases by 51%. NOx is maximum at a temperature of 250°C and is increased by 246.5%. This shows that preheating leads to improved combustion resulting in reduction in CO and HC. This also results in increase in NOx as evidenced in graph.

![Figure 13. BP variation with fuel temperature](image1)

![Figure 14. BSFC variation with fuel temperature](image2)

4. Conclusion

The experiments done by heating diesel fuel to a high temperature before injecting into the combustion chamber of a diesel engine shows that it has a benefit on improvement of performance and reduction in emission. Experiments were conducted at standard injection timing and results were shown for 50% and 75% of full load at different temperature. Results at 50% load is more encouraging than at 75% load. At 50% load, BSFC decreases by about 7.4%, BTE improves by 1.4%, HC and CO decreases by 51% and 38% respectively. Increases in NOx shows combustion is improving. Thus, it can be concluded that fuel heating before injection has advantages but it is sensitive to injection timing and engine loads. More experimentation is needed to understand the effect of injection timing on performance and emission of diesel engine.

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