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EFFECT OF EXHAUST GAS RECIRCULATION ON PERFORMANCE AND COMBUSTION CHARACTERISTICS ON A DI DIESEL ENGINE

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***Abstract*: In recent years, internal combustion engines are the major power source in the heavy transportation sector as well as in individual transport. In that diesel engine plays an important role and is the most preferred because of its better drivability, high efficiency and robust structure. Despite these advantages diesel exhaust emissions contains gases like HC, CO, Nitrogen Oxides (NOX) and soot particles. These emissions create problems for both humans and environment and therefore they have to be limited. Henceforth, strict emission norms are introduced by the authorities as per BS 6 Norms in most countries. Out of these emissions NOX is major concern for diesel engines. This paper deals with the study on the effects of exhaust gas recirculation on the performance and combustion characteristics on a Di-Diesel Engine**

Keywords: *Exhaust Gas Recirculation, Diesel engine, Emission control, Combustion performance*

I INTRODUCTION

In modern diesel engines, the EGR gas is cooled with a heat exchanger to allow the introduction of a greater mass of recirculated gas. Unlike SI engines, diesels are not limited by the need for a contiguous flame front. Furthermore, since diesels always operate with excess air, they benefit from EGR rates as high as 50% in controlling NOX emissions [1]. Exhaust recirculated back into the cylinder can increase engine wear as carbon particulate wash past the rings and into the oil.

Since diesel engines are unthrottled, EGR does not lower throttling losses in the way that it does for SI engines [2]. Exhaust gas largely carbon dioxide and water vapor has a higher specific heat than air, so it still serves to lower peak combustion temperatures. However, adding EGR to a diesel reduces the specific heat ratio of the combustion gases in the power stroke [3]. This reduces the amount of power that can be extracted by the piston. EGR also tends to reduce the amount of fuel burned in the power stroke. This is evident by the increase in particulate emissions that corresponds to an increase in EGR [4]. Particulate matter (mainly carbon) that is not burned in the power stroke is wasted energy. Stricter regulations on particulate matter (PM) call for further emission controls to be introduced to compensate for the PM emissions introduced by EGR [5]. The most common is a diesel particulate filter in the exhaust system which cleans the exhaust but reduces fuel efficiency. Since EGR increases the amount of PM that must be dealt with and reduces the exhaust gas temperatures and available oxygen, these filters need to function properly to burn off soot [6]. Automakers inject fuel and air directly into the exhaust system to keep these PM filters from becoming blocked up. By feeding the lower oxygen exhaust gas into the intake, diesel EGR systems lower combustion temperature, reducing emissions of NOX [7]. This makes combustion less efficient, compromising economy and power. The normally "dry" intake system of a diesel engine is now subject to fouling from soot, unburned fuel and oil in the EGR bleed, which has little effect on airflow, however, when combined with oil vapor from a PCV system, can cause buildup of sticky tar in the intake manifold and valves. It can also cause problems with components such as swirl flaps, where fitted. Diesel EGR also increases soot production, though this was masked in the US by the simultaneous introduction of diesel particulate filters [7,8]. EGR systems can also add abrasive contaminants and increase engine oil acidity, which in turn can reduce engine longevity [9]. NOX emissions can be reduced by lowering the cylinder temperatures. This done by three ways enriching the air fuel mixture Lowering the compression ratio and retarding ignition timing and Reducing the amount of Oxygen in the cylinder that inhibits the combustion process [10].

The first two methods reduce the efficiency of combustion and so the best way is to reduce the amount of Oxygen. This is done by recirculating some exhaust gas and mixing it into the engine inlet air. This process is known as Exhaust Gas Recirculation (EGR). In this work the effect of EGR on the performance and combustion characteristics of a DI diesel engine is carried out.

II EXPERIMENTAL SETUP AND METHODOLOGY

A single cylinder constant speed diesel engine generator set was chosen to study the effect of EGR on the performance and emissions, carbon deposits, and wear of diesel engine components. The specifications of engine are given in Table 1. The engine is coupled with an AC generator and the current generated is used by a resistive load bank, thus in-turn loading the engine. For recirculation of the exhaust gas, appropriate plumbing was done. No insulation on the pipe line was provided therefore allowing the re-circulated exhaust gases to partially cool down. The schematic diagram of the engine setup is shown in the fig.1 the quantity of EGR can be regulated by a control valve installed. To achieve the objectives of the study, engine was run under normal operating condition and at different EGR rates. The data for HC, NOx, CO, smoke opacity, exhaust gas temperature, and fuel consumption were recorded. Then, engine performance and emission patterns were compared. The helical coil shell type heat exchanger consists of a coiled channel with a heat transfer between a hot liquid with high boiling point (oil) and an ambient liquid (water). The ambient temperature liquid is allowed to flow in the helical pipe of diameter 48mm which is placed in an annulus pattern. The second intermediate water fluid is allowed to flow in a second channel of diameter 16mm which is the outer concentric pipe. The aluminum tube is placed inside shell diameter of 150mm.

The hot oil flows in the inner pipe thus the heat transfer to the water fluid in the next pipe were the heat can transfer to the water fluid from the water fluid heat is transferred to the next pipe were the water flow at the ambient temperature. Thus the heat transfer increases due to the larger mass and heat transfer region from shell to tube. Thus the heat transfer takes place from fluid to solid and solid to fluid.

The input and output temperatures of the fluid and the temperatures of pipe wall were measured with Fe-Const thermocouples with a multichannel digital thermometer. The outer surface of the heat exchanger was insulated by fiberglass. The flow rates of were measured with rotameters. The manometers of water were used for determining the pressure losses on the air side, while looses on the water side were determined by U manometers of

Table 1 Engine Specification

Make type	Kirloskar
Engine type	Single cylinder water cooled engine
Stroke	110 mm
Bore	80 mm dia
Rated power	3.75 kw
Compression ratio	16.5:1
Rated speed	1500 rpm
Loading device	Rheostat

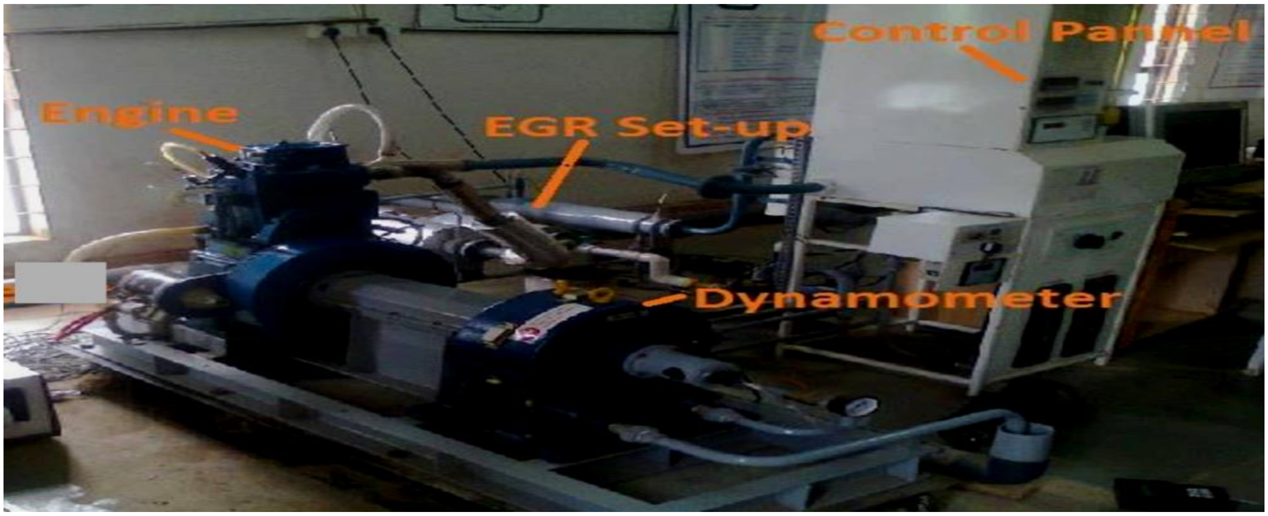

Fig. 1 Pictorial Representation of Compression Ignition Engine

CALCULATION

In the calculation worked on to find Brake power, Total Fuel Consumption, Specific Fuel Consumption, Brake Thermal Efficiency, Mechanical Efficiency.

1. Brake power(B.P)

BP = V X I / (1000 X ηg) kW

Where,

BP - Brake power in kW

V - Volt meter reading in volts

I - Ammeter reading in Amps

ηg -Generator efficiency

2. Total fuel consumption (TFC)

TFC = (X/ t) X (s/1000) X 3600 kg/ hr

Where,

X - Fuel consumption in cc

t - time for 20cc of fuel consumption in sec

s - specific gravity of diesel

3. Specific fuel consumption (SFC)

SFC = TFC/ BP kg/kW -hr

Where,

TFC - Total fuel consumption in kg/hr

BP - Break power in kW

4. Brake thermal efficiency (ηbth)

η_{bth} = (BP X 3600) / (TFC X CV) X 100

Where,

TFC - Total fuel consumption in kg/hr

CV - Calorific value in kJ/kg

5. Mechanical efficiency (ηm)

ηm = BP / IP X 100

Where,

IP - BP + FP

IP - Indicated power in kw

BP - Break power in kW

FP - Frictional power in kw

III RESULTS AND DISCUSSION

Performance Characteristics

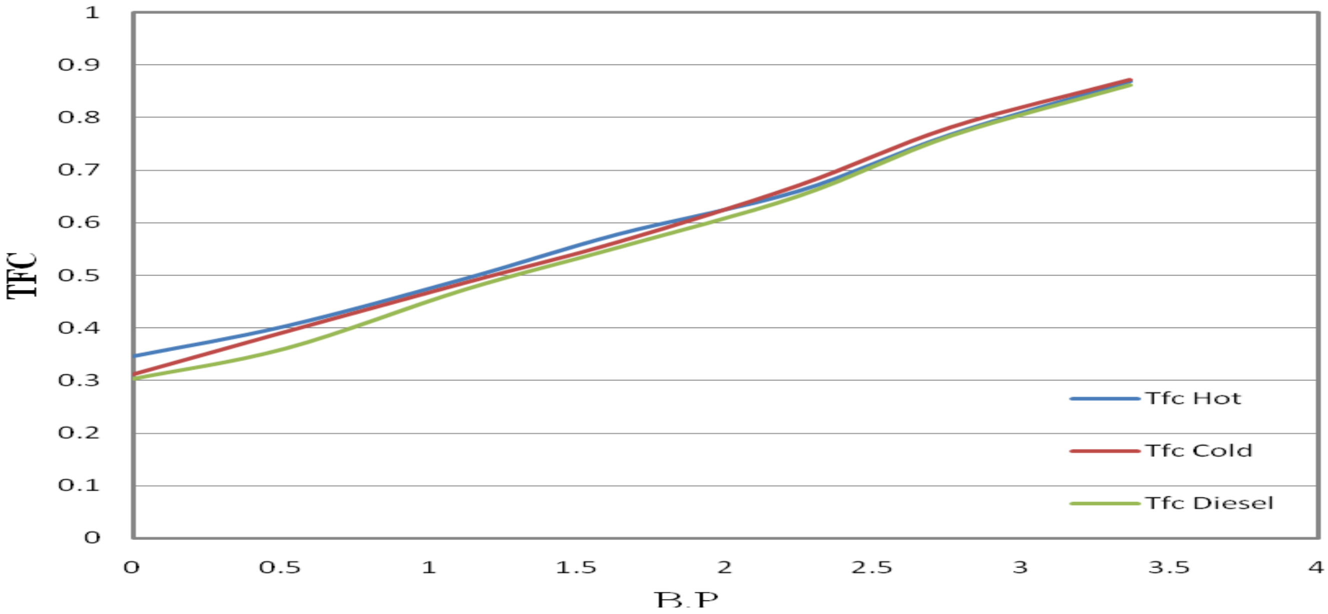

Fig.2 Variation of Brake Power Vs Total Fuel Consumption

3.1 Total Fuel Consumption

The variation of fuel consumption of the engine with and without EGR system at various Brake Power is shown in Figure 2. As shown in figure, when Brake power of the engine increases, the fuel consumption of the engine also increases. Fuel Consumption varies from 0.346 kg/hr to 0.8695 kg/hr for hot EGR and 0.3113 kg/hr to 0.8727 kg/hr for cold EGR and 0.3021 kg/hr to 0.8615 kg/hr for diesel engine respectively. Due to more fuel is required for same power output.

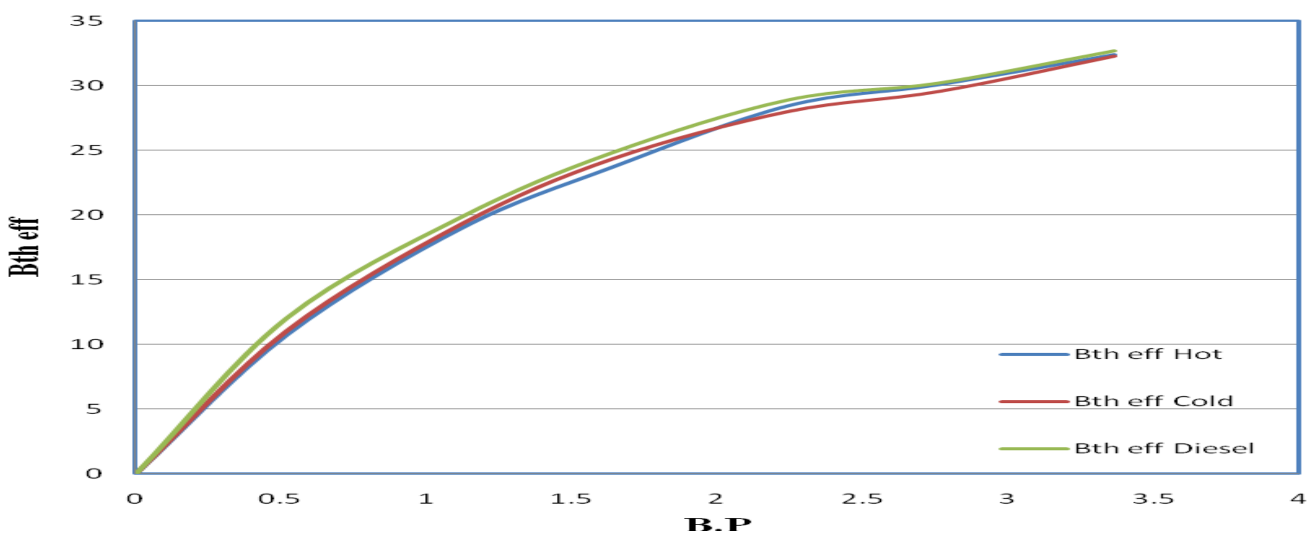

Fig.3 Variation of Brake Power Vs Brake Thermal Efficiency

3.2 Brake Thermal Efficiency

The Brake Thermal Efficiency variations with power output for the diesel. Due to fine mixture formation because of lower viscosity, lower density and high volatility. The maximum efficiency of the engine at the peak power output and it was 32.4% for hot EGR, 32.3% for cold EGR, 32.7 % for diesel because combustion rate is lowers, when EGR is used, due to low oxygen content in the intake.

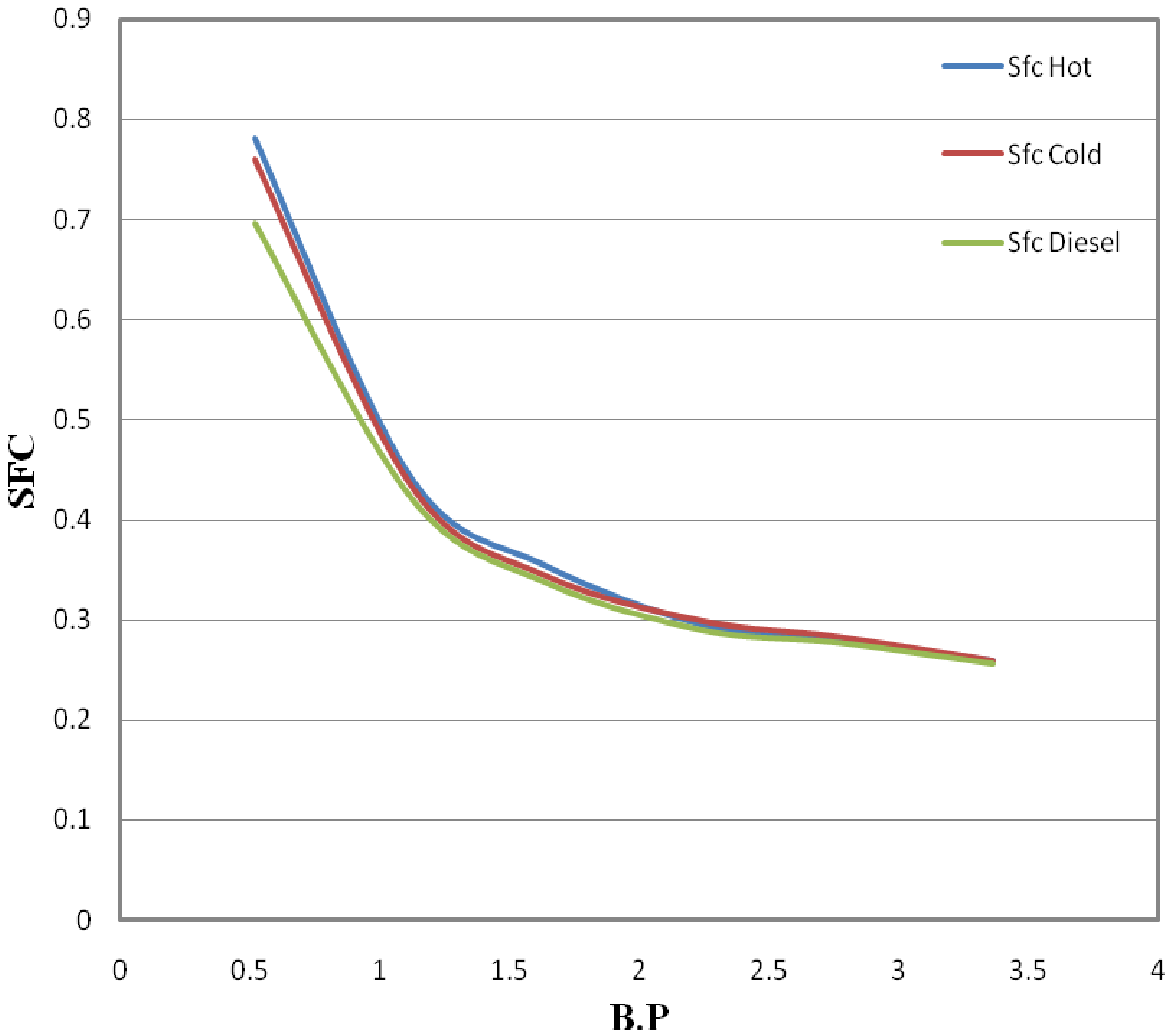

Fig.4 Variation of Brake Power Vs Specific Fuel Consumption

3.3 Specific Fuel Consumption

The variation of specific fuel consumption of the hot and cold with diesel. The specific fuel consumption for hot and cold EGR is higher than diesel at all loads. This is because of lower calorific value, high viscosity and poor volatility of the fuel. As the volatility is poor, the quantity of fuel utilized for an equal power as compared to that of diesel is more which results in more specific fuel consumption.

3.4 Combustion Analysis

A detailed experimental description of combustion evolution in diesel engine is extremely complex because of the simultaneous formation and oxidation of air/fuel mixture, however an effort has been made to study the effect of biodiesel on different parameters like maximum combustion pressure and corresponding crank angle in degree (deg CA), rate of pressure rise and corresponding crank angle, start of fuel injection, ignition lag, and most importantly the heat release rate and combustion zones in the combustion chamber of the engine.

The variation of cylinder peak pressure with crank angle and heat released rate are shown above. From this figure it shows different load condition, figure 5 shows both the variation of crank angle with cylinder pressure and heat released at no load condition, diesel reached high pressure compared to hot and cold EGR, but heat has been released at high degree of rice bran bio diesel more than diesel from this due to high pressure of diesel producing high brake power then compared to hot and cold, to find the cylinder pressure and heat released rate. Full load condition the cylinder peak pressure and heat released rate reached at high state.

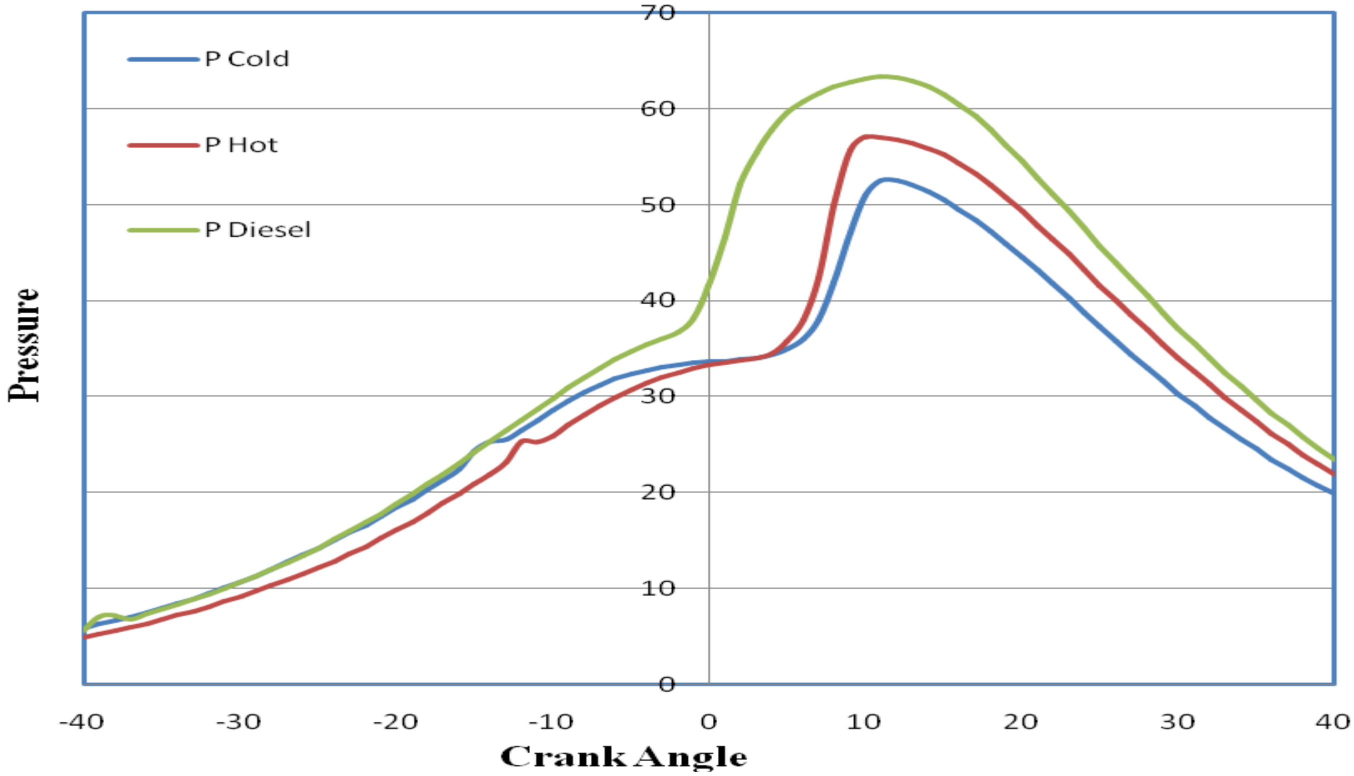

Fig.5 Variation of Crank Angle Vs Cylinder Peak Pressure in Full Load

The graph shows the variation of peak pressure and crank angle. In engine the crank shaft rotates at certain angle and reached at high point is called top death centre, from this graph diesel reached the high peak pressure. Because of less availability of oxygen in the intake, rate of combustion will be less resulting in less peak pressure.

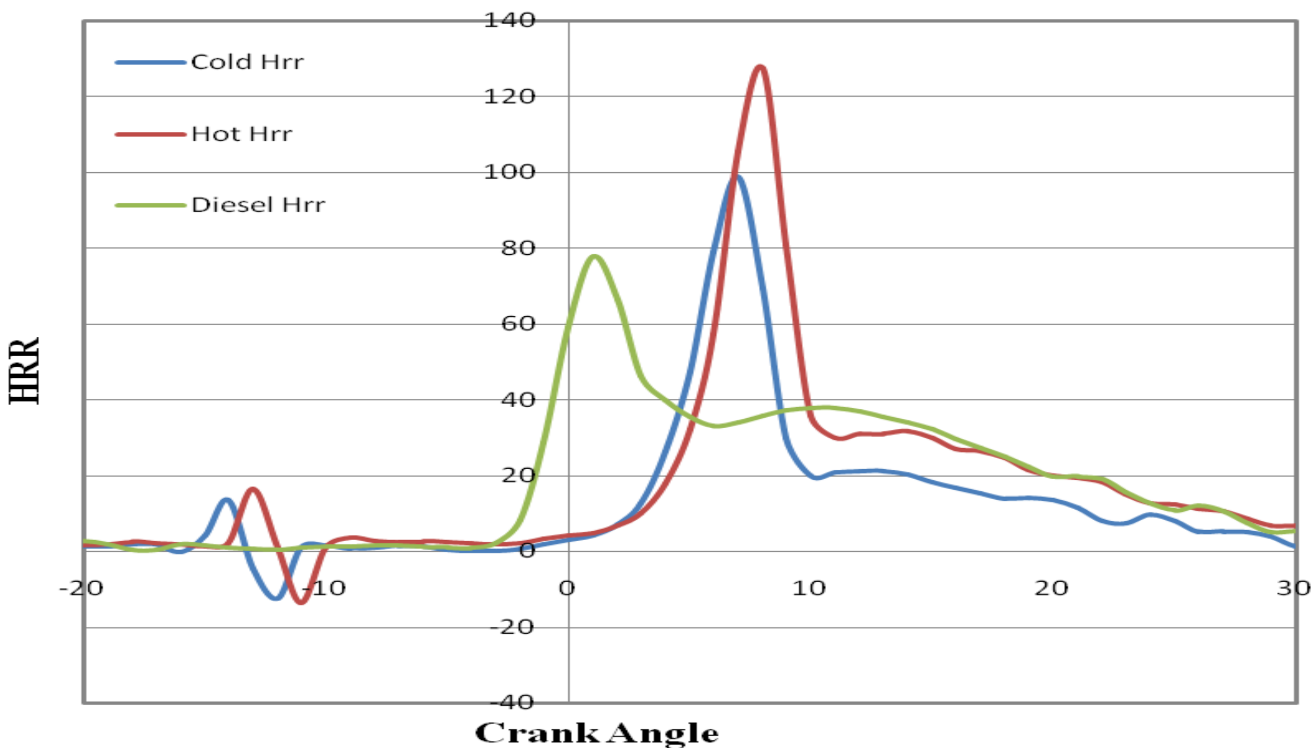

Fig. 6 Variation of Crank Angle Vs Heat Released Rate in Full Load

The above graph shows the variation of crank angle and heat released per rate. Here both the hot, cold EGR and diesel released the different heat values at different angle. When the timing of rotating crank shaft at different angle it reflect the variation of heat released per rate. Hot and Cold EGR has high flaming content compared to diesel. When compared to cold EGR than hot EGR, it is having higher heat release; this is because of higher temperature of gases which improves fuel atomization and ignition delay resulting in better combustion.

IV CONCLUSION

This study gives an overview over different ways to achieve EGR flow in diesel engines. Advantages and drawbacks of these ways are analyzed and compared with regard to fuel consumption. It is shown that the Hot EGR path leads to lower fuel consumption.

- The effect of EGR can be found predominant in reduction of NOX which is indicated by the reduction in cylinder pressure and heat release.
- Comparing the Hot EGR and Cold EGR, Hot EGR has the greater advantage if it is well designed.
- There is a slight increase in efficiency of engine while using Hot EGR.
- In this research, Diesel is utilized as a fuel, there is a problem with increase in NOX emissions as well as there will be reduction in performance of the engine. But if EGR technique is incorporated with the diesel, then there will be greater advantage of increasing the performance of engine as well as combustion.
- So taking all the results into consideration from the present experiment, Hot EGR with 15% exhaust gas recirculation would result in optimum engine. In the contrary, it is important not to cool the EGR too much, as condensation droplets could be a problem inside the combustion chamber. The Cold EGR system has a slower response to changes in the EGR demand than the Hot EGR system, because of its higher temperature that is filled with a mixture of fresh air and EGR.

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