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# EXPERIMENTAL STUDY ON SINGLE CYLINDER DIESEL ENGINE FOR EXHAUST WASTE HEAT RECOVERY

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## Abstract-

***Diesel Generating set (DG Set) is more popular and being used as standby unit where there is increasing demand for energy specifically when load shading problems are severe. The commercial and domestic use of DG Set by industrialist and farmers is increasing as captive power plant. This is due to its low start up period and easy to handle. The popularity of DG set increasing but there are various losses associated with diesel engine which tends to reduce its efficiency. The exhaust gas loss which contributes almost 33% is major loss which reduces the performance of the engine. Alongwith losses there are diesel engine produces a large amount of smoke and NOx which is harmful to the enviornment. It would be realistic to assess the waste recovery potential in the exhaust. This paper is concern towards recovery of waste heat by means incorporation of specifically designed heat exchanger to extract the heat from exhaust flue gases and heat the inlet air passed to the engine. The emphasis is given to experimentally find the effect on inlet air temperature, exhaust air temperature and air fuel ratio with brake power. This experimentation shows there is possibility to recover exhaust heat to some extend by incorporation of heat exchanger.***

***Keywords:*** *Diesel Engine; Air Fuel Ratio; Exhaust Gas Temperature*

## I. INTRODUCTION

The popularity of DG set increasing but there are various losses associated with diesel engine which tends to reduce its efficiency. The exhaust gas loss which contributes almost 33% is major loss which reduces the performance of the engine. Alongwith losses there are diesel engine produces a large amount of smoke and NOx which is harmful to the enviornment. It would be realistic to assess the waste recovery potential in the exhaust. Many researchers have been tried to investigate on harnessing this heat from exhaust of diesel engine. Mori et al.[1] studied thermoelectric devices for finding potential in for vehicles. They predicted to achieve fuel economy efficiency of 4.7%. They found there are mainly two possible sources of waste heat (i) The exhaust gas system & (ii) radiator. Zhang & Chan [2] stated to install thermoelectric generators (TEG) for exhaust gas system. Yu & Chau [3] suggested use og TEG for waste heat recovery system using Cuk Convertor. Musu et al.[4] found Homogeneous Charge Progressive Combustion (HCPC) suitable in reduction soot and NOx at all operating conditions. Rathavi et al.[5] made use of heat exchanger accumulator mechanism for mixture formation. They modified four stroke, single cylinder, and direct injection diesel engine to operate in dual mode without diesel vapour mixture and with diesel vapour mixture formation of fuel. The experimentation is conducted on single cylinder four stroke diesel engine for controlling cylinder peak temperature with Exhaust gas recirculation (EGR) methods which have been found beneficial to reduce NOx emission[6].The extensive research using heat exchanger have been taking place to recover the waste heat from exhaust of diesel engine.This heat exchangers helpful to improve the performance and reduce the emission levels. The specially designed heat exchangers extracting potential heat from exhaust of engine [17]. Thakar et.al designed shell and tube heat exchanger based on the potential of heat availabe at the engine exhaust of single cylinder four stroke diesel engine and reported improvement in engine performance and reduction in smoke level [8]. Many Researchers have been applying different techniques to improve thermal efficiency of diesel engines. The effect of increase in injection pressure from 100 to 300 bar and cylinder air pressure from 10 to 25 bar also have been investigated on combustion and heat release rate for DI diesel engines shown improved brake thermal efficiency [9].The present research is carried out on 5HP capacity, four stroke single cylinder, water cooled diesel engine with specifically designed heat exchanger and blower to study effect on inlet air temperature , exhaust gas temperature and air fuel ratio with brake power.

## II EXPERIMENTAL FACILITY, INSTRUMENTATION AND PROCEDURE

The setup consists of Single cylinder, 5 Hp, Kirloskar make, water cooled, Diesel Engine. The engine is attached with various attachments for measurement of different parameters. These are Dynamometers, Thermocouple setup, Manometer, Air box, etc. The thermocouples are used for measurement of temperature at various locations which are connected to control panel. Air box is used for measuring the amount of air supplied to the engine and volumetric type method used for measurement of fuel consumption. The three trials had been conducted to carry the present research on recovery of waste heat from exhaust of diesel engine. These trials are for i. Basic engine setup ii. Setup with specifically designed heat exchanger iii. Setup with Heat Exchanger and blower. The trial on basic engine setup was taken for injection timing of 26° BTDC at atmospheric temperature. The trials for remaining two setups were taken for injection timing 23° BTDC. The heat potential at the exhaust is calculated on the basis of experimentation on basic engine setup for no load to full load capacity. Depending on the heat potential availability at full load counter flow rectangular type shell and tube heat exchanger was designed. This heat exchanger was incorporated between exhaust and suction line of the engine. The trials ii and iii conducted with this heat exchanger . The basic experimental setup is shown in Fig.1.

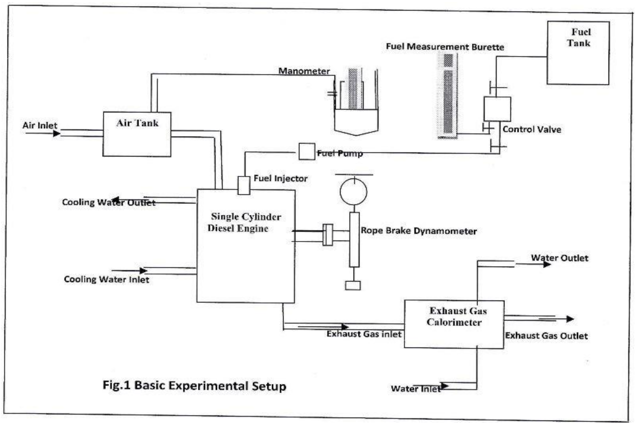


Figure 1:Basic Experimental Setup

Table 1 Details of the Diesel Engine

| | | | |
|---|---|---|---|
| Bore | = 80 mm | Fuel injection release pressure | = 200 bar |
| Stroke | = 110 mm | Pumping clearance | = 0.85 to 1.06 mm |
| Rated speed | = 1500 rpm | Valve tappet cleara (when enquire is cc | At inlet = 0.203 mm At exhaust = 0.254 mm |

| | | | |
|---|---|---|---|
| Rated horse power | = 5 H.P. | Engine oil used | = SAE 40 |
| Fuel injection timing | = 26 ° before TDC | Compression ratio of the engine | = 16.5 |

## III RESULTS AND DISCUSSION

The experimentation on 5HP capacity , 4-stroke single cylinder ,water cooled, kirloskar make stationary diesel engine was performed at inlet air temperature 30 °C and injection timing 26 °C before TDC. The potential heat available at the exhaust at full load taken into consideration and the counter flow shell and tube type heat exchanger rectangular type was designed and fabricated. This heat exchanger is used to recover the exhaust waste heat and heat the inlet air passed to the cylinder. Three trials have been conducted for three cases that is i.basic engine setup ii. Modified engine setup with designed heat exchanger and iii.Modified engine setup with heat exchanger and blower. The experimentation is conducted and evaluated the performance parameters exhaust gas temperature, inlet air temperature and air fuel ratio at various load conditions. It is found temperature of inlet air increases gradually with increase in load. The Performance characteristics for these kinds of tests explained in details in the following section.

### 3.1 EFFECT ON INLET AIR TEMPERATURE

The effect of inlet air temperature is observed at various loads. The variation in the values for inlet air temperature plotted against the percentage brake power and shown in fig. 2. The suction air temperature was found to be constant i.e. 30 °C for no load to full load operating conditions for the engine running at normal condition.

The variation in the values for inlet air temperature at injection timing 23° before TDC with heat exchanger shown in fig. 2. The suction air temperature increases with engine running at injection timing 23° before TDC with heat exchanger and found to be increased with increase in load. When blower is used with heat exchanger, the velocity of air through the heat exchanger gets increased. Due to this the heat transfer time between fresh air and hot exhaust gases transfer reduced slightly.

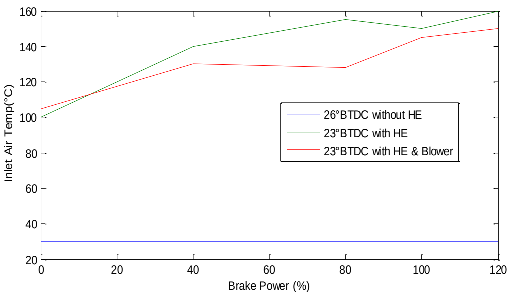


Figure 2:Variation of Inlet Air Temperature with Brake Power

### 3.2 EXHAUST GAS TEMPERATURE

The effect of Exhaust gas temperature is observed at various loads. The variation in the values for exhaust gas temperature plotted against the percentage brake power and shown in fig. 3. The exhaust gas temperature found to be increasing for increase in the load. The exhaust gas temperatures were 220, 310 and 370 °C at 50%, 100% and overload condition respectively for the engine running at normal condition.

The variation in the values for exhaust gas temperature at injection timing 23° before TDC with heat exchanger shown in fig. 3. The suction air temperature increases with engine running at injection timing 23° before TDC with heat exchanger and found to be increased with increase in load. The same is also observed with exhaust gas temperature which also increases with increase in inlet air temperature for this kind of arrangement. The exhaust gas temperatures obtained were 145, 152, 155 and 162 °C at 50, 70, 100% and overload condition respectively. The heat transfer time reduces when blower is used with heat exchanger which tends to reduce exhaust gas temperature.

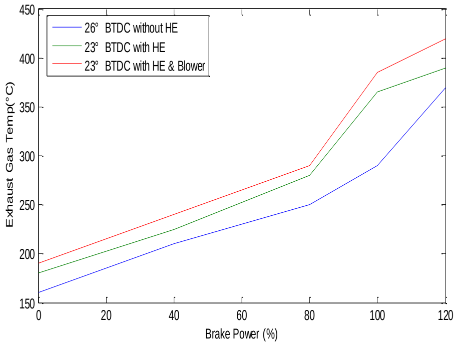


Figure 3:Variation of Exhaust Gas Temperature with Brake Power

3.3 EFFECT OF AIR FUEL RATIO

Fig.4 shows variation of air fuel ratio with respect to percentage brake power. It is found that air fuel ratio decreases as the brake power increases for engine running at normal condition. The air fuel ratio varies in between 64.10 to 22.76 under various operating conditions. The values of air fuel ratio obtained are 30.5 and 24.3 at 75% to 100% of brake power respectively. The graph shows that the air fuel ratios for different load conditions at injection timing 23° before TDC with Heat exchanger are lower than normal running condition. However, it is interesting to note that the difference between the air fuel ratio with normal operation and with heat exchanger is reducing as load approaches the full load. This is due to decrease in brake specific fuel consumption towards full load. At around full load, the air-fuel ratios for various operating conditions are nearly the same. There is drastically reduction in air fuel ratios beyond the full load. As the blower is connected to the heat exchanger, the density of air at the same temperature gets increased and the more amount of air is supplied to the engine.

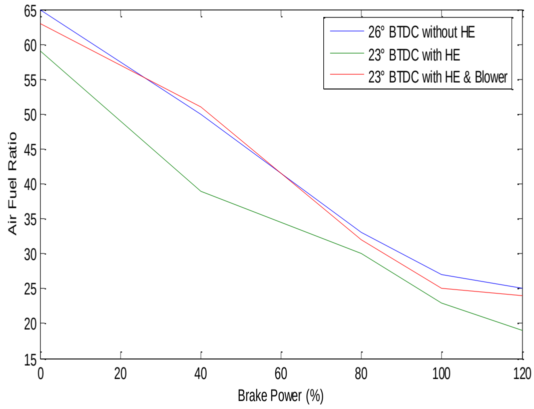


Figure 4:Variation of Air Fuel Ratio with Brake Power

## IV CONCLUSION

The experimental investigation shows increase in suction air temperature for experimental setup with heat exchanger and engine running at injection timing 23° before TDC which again found to be increased with increase in load. This depicts improved engine performance. However exhaust gas temperature also increases for increase in suction air temperature as load increases when engine is running with heat exchanger at injection timing 23° before TDC .When blower is used there is reduction in exhaust gas temperature is observed. It also shown air fuel ratios for different load conditions at injection timing 23° before TDC with Heat exchanger are lower than normal running condition

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