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Design of Heat Exchanger for Waste Heat Recovery from Exhaust Gas of Diesel Engine

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Abstract

The Diesel Generating set (DG Set) which uses diesel engine is gaining popularity in rural areas as it produces electricity for irrigation and agricultural purposes. But there are various losses associated with diesel engine which tend to reduce its efficiency and performance. Among these exhaust heat loss is major loss which contribute almost 33-36% and leads to the waste of heat which could be recovered and a considerable amount of primary fuel could be saved. The literature survey reviews that exhaust gases from diesel engine having heat potential that can be recovered. In the present paper attempt have been made recovering of waste heat energy of exhaust gas of diesel engine by placing specially designed heat exchanger just near the inlet and outlet duct of the engine so that energy from the exhaust can be used for preheating the air passed to the engine. A simple counter flow shell and tube type heat exchanger was designed and fabricated based on the output obtained from initial design. The experiments were conducted with and without out heat exchanger on vertical, single cylinder, 5 HP, cold start, water cooled, four stroke diesel engine working on high speed diesel oil .The diesel engine with incorporation of heat exchanger shows improved performance of engine and also shown reduction in smoke level.

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Keywords: Diesel Engine; Exhaust gas; Heat exchanger; Waste heat recovery; Preheat;

1. Introduction

Efficiency is probably most important performance parameter for diesel engine. The Exhaust gas loss is major loss that would have dominant effect on the performance of Engine. The temperature associated with the exhaust flue gases attributes towards the reduction in performance and increasing the emission level in the exhaust. Many means

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have been tried to utilize this heat of flue gases to improve the performance and reduction in emission level. The researchers experimented on various technologies to recover the waste heat from the internal combustion engines. The technologies like organic Rankine cycle looked into the potential energy savings and performance of these technologies [1]. Srinivasa et al. adopted the principle of electro turbo generation and reported the increase in useful work obtained from 25% to 25.025% in conventional internal combustion engine [2]. Janak Rathavi et al. experimented on DI diesel Engine modified to operate on a dual mode with and without diesel vapour mixture. They used heat exchanger- Accumulator mechanism to vaporize the diesel fuel and catalytic cracking. The method resulted into simultaneous and substantial reduction of Nox [3]. J.Ma et al. used biodiesels prepared from waste vegetable cooking oil, pongamia, rice brain oil, Pungam methyl esters [4.The biodiesel fuels proved to be good substitute to diesel fuel but increase in Nox emissions limited its usability in the existing engines. The investigation on use of CNG-Dual fuel mode in diesel engine showed promising technique for controlling the smoke emissions from existing Direct injection Diesel engines [5] .The improved results in performance for blended mode with biodiesel achieved may be due to increased injection pressure. Venkanna et al. studied effect of injection pressure with blends of 20% pongamiapinnatalinn oil and 80% diesel fuel in DI Diesel engine and reported increased injection pressure from 20% to 30% [6]. Subramanian et al. have investigated on the injection and spray characteristics of a diesel engine using blend of diesel with karanja biodiesel (B10 to B20) and reported the dynamic injection timing advanced for the biodiesel blends resulting in higher NOx emission. They also reported inline injection pressure increased from 460 bar with base diesel to 480 bar with B20 [7]. It is found that if the cylinder temperature exceeds 2000 K formation of NOx take place [8]. The experimental investigation on single cylinder four stroke diesel engine to control the cylinder peak temperature with Exhaust gas recirculation (EGR) methods have been reported beneficial to reduce NOx emission[9,].The extensive research have been taking place to recover the waste heat from exhaust of diesel engine using heat exchangers to improve the performance and reduce the emission levels . The specially designed heat exchangers showed potential to recover the waste heat [10]. The present paper reports results of experimental investigation on single cylinder four stroke diesel engine operating on constant speed, where improved performance and reduction in smoke level are obtained by incorporation of specially designed heat exchanger to heat the inlet air.

2. Design and Calculations

2.1 *Waste Heat Recovery*

In designing the heat exchanger conventional notations are used. Waste heat recovery represents the amount of waste heat of the exhaust gas absorbed by the inlet air in the heat exchanger. For temperature of hot fluid on leaving the heat exchanger (Th_2) we use the heat balance equation. Heat absorbed by air = Heat carried by Exhaust gas

$$\text{i.e} \quad M_a C_{pa} \nabla_{ta} = m_e C_{pe} \nabla_{te} \tag{1}$$

The percentage of heat recovered can be calculated as

$$\% Q_{rec} = \left(\frac{Q_a}{Q_e} \right) \times 100 \tag{2}$$

2.2 Effectiveness

Effectiveness is the ability of heat exchanger to transfer heat of hot fluid to the cold fluid. The effectiveness of heat exchanger is given by

$$Effectivness = \left[\left(Th_i - Th_o\right) \big/ \left(Th_i - Tc_i\right) \right] \tag{3}$$

2.3 Heat Exchanger Design

To find the length of the tube (L) put the various values in heat transfer rate equation. The amount of heat transfer rate in the heat exchanger is given by,

$$q = F\,U\,A(LMTD) \tag{4}$$

The correction factor is need to be multiplied to Log mean Temperature difference (LMTD) for multipass heat exchanger and it is to be averagely found from correction factor graph . This overall heat transfer coefficient is calculated considering that air is passed through the number of tubes made of copper and exhaust gases pass through shell of exchanger which comprises these number of tubes. The (LMTD) is given by

$$LMTD = \left[\left(Th_1 - Tc_2\right)\left(Th_2 - Tc_1\right) \Big/ \log_e\left(\left(Th_1 - Tc_2\right) \Big/ \left(Th_2 - Tc_1\right) \right) \right] \tag{5}$$

3. Experimentation

The present investigation is carried out on vertical, single cylinder,5 HP, cold start, water cooled, four stroke, Kirloskar make, diesel engine working on high speed diesel oil .The two trials have been conducted viz. i. Performance of stationary diesel engine at normal running conditions i.e. 26° BTDC at atmospheric temperature and ii. Performance of stationary diesel engine at injection timing 23° BEFORE TDC with Heat Exchanger.

4. Results and Discussion

The Performance characteristics for this kind of test explained in details in following section.

4.1 Effect on Inlet air temperature and Exhaust gas temperature

The effect of inlet air temperature and Exhaust gas temperature is observed at various loads. The variation in the

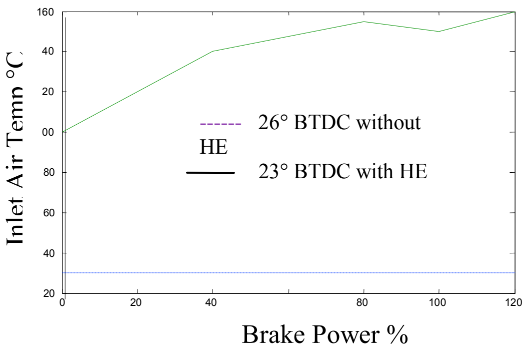

Figure 1:Variation of inlet air temperature of the engine with brake power

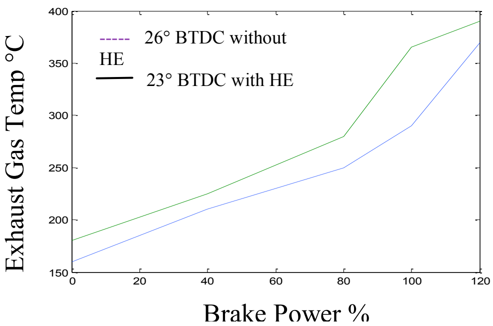

Figure 2:Variation of exhaust gas temperature of the engine with brake power

values for inlet air temperature and exhaust gas temperature plotted against the percentage brake power and shown in fig. 1 and Fig.2 respectively. The suction air temperature was found to be constant i.e. 30 °C for no load to full load operating conditions. There 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 experimental setup with heat exchanger the suction air temperature increases with this kind of arrangement 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. The exhaust gas temperatures obtained were 145, 152, 155 and 162 °C at 50, 70, 100% and overload condition respectively.

4.2 Effect on Thermal Efficiency

The brake thermal efficiency is calculated for different operating conditions. The graph is plotted for brake thermal efficiency vs percentage brake power. The graph shown in Fig.3 shows the variation of brake thermal efficiency with respect to percentage brake power for different operating conditions. The trend shows increase in the thermal

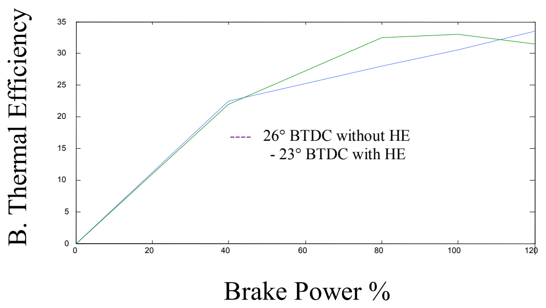

Figure 3: Variation of brake thermal efficiency with brake power

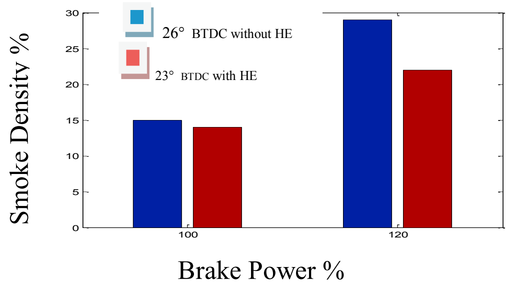

Figure 4: Variation of smoke density with brake power

efficiency with brake power and reaches to maximum around full load condition and further decreases beyond full load. For the experimental setup with heat exchanger the variation of brake thermal efficiency at different outputs is given in fig.3. It is clear that thermal efficiency reaches maximum and then decreases. It indicates that inlet air heating improves performance at full load and beyond full load it gets deteriorated. At 100% load thermal efficiency rises due to increased inlet air temperature which leads to proper mixing of fuel and improves vaporisation of injected fuel. At 100% and 120% of brake power thermal efficiencies obtained were 32.5 and 28.9. From graph it is clear that the performance of the engine with inlet air heating is better than normal heating conditions. However beyond full load it gets deteriorated.

4.3 Effect on Smoke density

The percentage of smoke density with respect to brake power is as shown in fig. 4. It shows that at full load the smoke density was 15% and for overload condition it was 29%. For the experimental setup with heat exchanger it is clear that there is reduction in smoke level when engine is operating at 23° before TDC with heat exchanger as compared to engine operating at normal operating conditions. The values of smoke density at full load were 14% and at overload it was 22%.

5. Conclusion

The heat exchanger designed for the purpose of recovering the waste heat from the exhaust gases and to heat the inlet air up to 150°C at full load by using this heat is working satisfactorily. The inlet air heating improves the performance of the stationary diesel engine and lowers down the emission level. The effectiveness of heat exchanger found to be 0.615 at full load condition.

References

[1] M.T.Saeed, J.M.Biglari, A Comprehensive Study of Waste heat Recovery from Internal Combustion Engines using Organic Rankine Cycle, Thermal Science ,17(2012) 611-624.

[2] S.N.S. Prasad, N. Parameshwari, A feasibility Study on Waste Heat Recovery in an IC Engine using Electro Turbo Generation, Proceedings of national conference on Trends and advances in Mechanical Engineering , YMCA University of science & Technology, (2012) 55-60.

[3] J.Rathavi, A.Paul, G.R.Selokar, Experimental study of waste Heat recovery Technique to Increase efficiency and to decrease hazardous emissions in CI Engine, International Journal of Computational Engineering Research ,2(2012)204-213.

[4] J.Ma, X.Lu, L.Ji, Z. Huang, An experimental study of HCCI-DI combustion and emissions in a diesel engine with dual fuel, International Journal of Thermal Sciences ,47(2008) 1235-1242.

[5] W.A.Abdelghaffar, Performance and Emission of a Diesel Engine Converted to Dual Diesel- CNG Fuelling, European Journal of scientific Research ,56(2011) 279-293.

[6] R. Singh, S.Maji, Performance and Exhaust Gas Emissions Analysis of Direct Injection CNG-Diesel Dual Fuel Engine, International Journal

of Engineering Science and Technology,4(2012) 833-846.
[7] K.A.Subramanian, S.Lahane ,Comparative evaluations of injection and spray characteristics of a diesel engine using karanja biodiesel–diesel blends, International Journal of Energy Research ,37(2013)582-597.
[8] A.M.Wankhade, P.G.Sapre, S.D.Nagulkar, P.A.Bhargade , Effect of EGR on NOx & Performance Parameters in single cylinder four stroke CI engine, International Journal of Engineering Research and Development, 10(2014)59-67.
[9] K.Senthilkumar, P.Palanisamy,Experimental Investigation On Diesel Engine Exhaust Gas Heat Recovery Using A Concentric Tube Heat Exchanger With Transitory Thermal Storage, Australian Journal of Basic and Applied Sciences,8(2014) 194-206.
[10] P.Ramade, P.Patil, M.Shelar, S.Chaudhary, S.Yadav, S.Trimbake, Automobile Exhaust Thermo-Electric Generator Design & Performance Analysis, International Journal of Emerging Technology and Advanced Engineering ,4(2014) 682-691.