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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

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

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,

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