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Waste Heat Recovery from IC Engine using Shell and Tube Heat exchanger And Phase change materials

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ABSTRACT

Almost 15-20% of the heat generated during the combustion process in an Internal Combustion Engine (ICE) is released as such to the atmosphere. Waste Heat, also called as Secondary heat, generally refers to heat liberated from the chimneys of many industrial plants, outdoor unit of air conditioners, refrigeration units, radiators, furnaces, diesel locomotives etc. that has been expelled to the atmosphere without doing any useful work. This presents a great opportunity to conserve and utilize the waste heat which would otherwise be lost to the atmosphere. Waste heat recovery system (WHR) is used to achieve this purpose. The major technical constraint that prevents the recovery of waste heat is its irregular and intermittent availability. In the present work, heat recovery system consisting of shell and tube heat exchanger and a thermal energy recovery (TER) tank which stores the phase change material (PCM) is designed and fabricated for waste heat recovery from diesel engine exhaust.

Keywords: Phase change materials; Waste heat recovery**;**

1.0 Introduction

According to BP energy outlook 2018[1], energy consumption is set to increase by around a third or so by 2040. The global primary energy consumption is forecasted to increase from 13276MT in the year 2016 to almost 17983MT by 2040. The most alarming issue is the fact that 75% of this total demand in 2040 is to be met by non- renewable source like oil (27%), Gas (26%) and coal (21%). This is going to further aggravate the issue of depleting reserves of fossil fuel resources. World proven petroleum oil reserves at the end of 2012 reached 1668.9 billion

barrels, sufficient to meet 52.9 years of global production. As a result, fuel price will face a price hike in future year.

This situation implores scientists and researchers to search for different sources of energy as well as to increase the efficiency of energy conversion systems such as internal combustion engine (ICEs).Since the waste heat produced from various source can be used as a potential source of energy, we can develop innovative methods to utilize this untapped source of energy. Waste heat is generated in diesel engines due to the combustion of consumed fuel. If this waste heat could be recovered, a considerable amount of primary fuel can be saved. Latent heat storage is majorly concentrated because of its ability to provide high energy storage density and its characteristics to store heat at constant temperature. S.P.Raja, R.Rajavel and D.Naveenthakrishnan [2] performed an experimental investigation on heat recovery and were able to extract a maximum heat of 3.5KW. Zalba et al. [3], Sharma et al. [4] and Jagadheeswaran et al. [5] presented an outlook on the use of phase change material for thermal energy storage.

1. Experimental Setup

An unmodified kirloskar dual-cylinder compression ignition diesel engine having an engine displacement of 1500cc and maximum speed of 1500rpm was used as the heat generating unit. The exhaust gas of the diesel engine is made to pass through the shell side of the heat exchanger as shown in figure2. The fuel consumed by the diesel engine is measured using a U-tube manometer. The various heat losses can be calculated from the heat balance sheet and the inlet air consumed can be measured by using the air box method. The heat transfer fluid, Ethylene glycol $(CH2OH)2$ is passed through the tube sides and absorbs the heat from the exhaust gases. This HTF is then made to flow through the TER tank, in copper pipes passing alternatively in and out from the sides of the TER tank. The TER tank is divided into two well insulated compartments each containing a different PCM. The insulation is achieved with the help of aluminium foils. The copper pipes carrying the HTF flow through all the compartments at various points can be measured using a copper -constantan thermocouple.

2. Working

The Heat Transfer Fluid is initially pumped to the tubes of the Shell &Tube Heat Exchanger where it absorbs the heat energy of the exhaust gases. Exhaust gases at very high temperature are passes through one side of the shell and come out at normal temperature to through the other side and are discharged to the atmosphere as shown in figure3. The heated HTF is now made to pass through the TER tank where the PCM's absorb the heat. Since the phase change material has high latent heat of vaporization, they can reach very high temperatures without changing their states .The heat stored in the TER tank can be used for cabin heating (or) to overcome cold start problems in automobiles. Also a thermoelectric generator can be used to produce optimum amount of electrical energy to charge a battery.

3. Materials

3.1 Heat transfer fluid

We are using ethylene glycol $(C2H6O2)$ as our heat transfer fluid because of its high specific heat and thermal conductivity properties. It is widely used as an antifreeze agent in

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automobile. It is odourless, colourless and sweet-tasting liquid which is moderately toxic in nature.

3.1.2PCM

The three phase change materials that we are using are sorbitol, catechol and succinic anhydride. The first PCM that we are using is catechol ($C_6H_6O_2$) it is present as white feathery crystals and hence is mixed with water in the ratio of 430g/l. it has the highest auto-ignition temperature of 510ºC.The next PCM that we are using is Sorbitol, a polyol (sugar alcohol) and is found in numerous food products as a sweetening and texturizing agent. It is present in liquid at STP and has high auto-ignition temperature of 420ºC.The third and final PCM is succinic anhydride ($C_4H_4O_3$).It too has a high auto-ignition temperature of 300ºC. It is a colourless solid and is stored in the liquid state by mixing it in ethanol (2.56g/100ml).

4.Test Procedure

The diesel engine is warmed up for a period of 15 minutes. An eddy current dynamometer is used to vary the load from 0 to 100% in steps of 25% each. The temperature of the exhaust gases is measured for each increment inload using Copper-Constantan thermocouple. The mass flow rate of the Heat transfer fluid is also varied according to the load. P.Purushothaman et.al [6] used a similar method for their experimental work on emission characteristics of novel peppermint oil blends.

Fig 3 Experimental set-

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LOAD (%)	% OF EXHAUST HEAT RECOVERED
0	0
10	7.55
20	13.21
30	21.65
40	29.75
50	37.73
60	45
70	53.82
80	58.97
90	65.11
100	70

Fig.1 Table comparing the % of exhaust Thermal heat recovered at various loads

CONCLUSION

The exhaust gas of a diesel engine carries about 20% of the Indicated power and as shown in the Load curve table (Fig.1),almost 70% of the total thermal energy coming out of the exhaust gases can be recovered to produce additional power. The main aim of this project is to utilize the waste heat energy for the generation of electrical energy using a thermoelectric generator which can be further utilized to charge an on-board battery unit which can be used to run the automobile. Thus the consumption of fuel can be reduced which in turn reduces the emissions.

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