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SUITABILITY AND PERFORMANCE ANALYSIS OF VAPOUR ABSORPTION SYSTEM USING ENGINE EXHAUST ENERGY

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Abstract

The exhaust gas from an internal combustion engine carries away about 1/3rd of combustion heat. The exit stream of gas will provide an important heat source that will be utilized in a number of ways to provide additional power and improves overall engine efficiency. The foremost technical constraint that prevents successful implementation of waste heat recovery is due to its intermittent and time mismatched demand and availability of energy. In the present work, a heat exchanger integrated with an IC engine setup to extract heat from the exhaust gas and used to operate the generator of the vapour absorption system. By the suitability analysis, found that exhaust gas has a heat capacity of 2.85kW at low load conditions and it is enough to operate the vapour absorption system by control the flow rate of refrigerant and exhaust gas at various conditions. The performance parameters pertaining to the vapour absorption system and multi cylinder engine such as amount of exhaust gas flow rate, heat capacity, suitable flow rate are evaluated.

Index Terms: Exhaust, Waste heat, Generator, VAR, Ammonia.

INTRODUCTION

Considering the environmental protection and also in the context of great uncertainty over future energy supplies, attention is focused on the utilization of sustainable energy sources and the energy conservation methodologies. High capacity engines are one of the most widely used power generation units. Nearly two-third of input energy is wasted through exhaust gas and cooling water of these engines. It is imperative that a serious and concrete effort should be launched for conserving this energy through waste heat recovery techniques. Such a waste heat recovery would ultimately reduce the overall energy requirement and also the impact on global warming.

Waste heat is generated in a process by the way of fuel combustion or chemical reaction, and then dumped into the environment, Even though it could still be reused for some useful and economic purpose. Large quantity of hot flue gases is generated from boilers, furnaces and IC engines etc., If some of this waste heat could be recovered, a considerable amount of primary fuel could be saved. The energy lost in waste gases cannot be fully recovered. However, much of the heat could be recovered and losses can be reduced by adopting certain measures like EGR and vapour absorption system.

LITERATURE REVIEW

The exhaust gases from cooling and power installations represents a significant amount of thermal energy that historically has been used for combined heat and power applications [1]. A combined sensible and latent heat storage system is designed, fabricated and tested for thermal energy using phase changing material capsules-10-15% fuel power combined storage system. The exhaust gas of a diesel engine carries a plenty of heat and this energy will be recovered efficiently using Heat Recovery [2]. The recovered heat is offer heat to an absorption refrigeration system (ARS). Various sources and levels of extracted heat loads were found to be within the range 58-

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62% of the heat supplied to the gas turbine plant. The result showed that the Coefficient of performance (C.O.P) is higher for Water-multi-component salt mixture than Water-LiBr solution [3]. Computing the dynamic heat exchanger model for predict performance and control for automotive waste recovery systems. Waste heat recovery by means of a Rankine Cycle is a promising approach for achieving significant reductions in fuel consumption and, as a result, exhausts emissions of passenger car engines [4]. The test was conducted on a light-duty gasoline engine connected with a multi-coil helical heat exchanger. Combining those experimental and modelling results, it demonstrates that the rate of flow of operating fluid plays a vital and complex role for controlling the steam outlet pressure and overheats degree [5].

An experimental study of an aqua-ammonia absorption system used for automobile air conditioning system, this system victimization exhaust waste heat of an internal combustion diesel engine as energy source. The energy availability that can be utilized in the generator and therefore result of the system on engine performance, exhaust emissions, auto air conditioning performance and fuel economy are evaluated [6]. The usage of an absorption refrigeration system power driven by waste heat from the electrical power generating gas turbine could provide the necessary cooling at reduced overall energy consumption. In this study, a potential replacement of propane chillers with absorption refrigeration systems was theoretically analyzed [7]. Most of the automobiles use vapour compression refrigeration system (VCR) for space cooling as well as transported goods or load refrigeration. One of the drawbacks of the automobile VCR system is that the compressor draws significant power from the engine, which decreases the overall efficiency of the vehicle [8].Two groups of configurations are examined: a classical shell and tube heat exchanger using staggered cross-flow tube bundles with smooth circular tubes, finned tubes and tubes with dimpled surfaces and a crossflow plate heat exchanger, initially with finned surfaces on the exhaust gas side and then with 10 ppi and40 ppi metal foam material substituting for the fins [9]. In the commercial vapour absorption refrigeration system a heating coil generator system has been employed to vaporize the ammonia refrigerant. In the present work, the heating coil generator system has been replaced by the frame plate type heat exchanger. The exhaust gases from the IC engine have been utilized to vaporize the ammonia refrigerant. The available heat in the exhaust gases has to be estimated based on actual I.C-Engine driving cycles. The frame plate type heat exchanger has to be modeled and flow analysis inside the heat exchanger has to be analyzed [10]. The vapour absorption system is the best refrigeration where it utilizes the waste heat effectively and it is best suited for chilling purpose. This work describes the suitability of waste heat energy from the internal combustion engine for operating the vapour refrigeration system.

VAPOUR ABSORPTION SYSTEM

In a typical vapour absorption system, ammonia is employed as the refrigerant because it possesses the desirable properties. It is toxic, but since the system has no valves or moving elements, there is very little chance or no probability of leak and also overall quantity of refrigerant change itself is small. Liquid ammonia of refrigerant charge itself is small. Liquid ammonia evaporates in the presence of air /other gases, the lighter than gas faster the evaporation. Since hydrogen is the lightest gas and is non corrosive and insoluble in water it is used in the low side of the system. Water is used as the solvent because of its ability to absorb ammonia readily.

If liquid ammonia is introduced at the top of the system as shown in fig. 1, it flows into the evaporator and evaporates. Hydrogen passes upward in the evaporator counter flow to the liquid ammonia that falls from one level to another at (4). The ammonia vapour and hydrogen leave the top of the evaporator and pass through the gas heat exchanger here they warmed by the hydrogen flowing in the evaporator. Then they flow through the vessel on the left and into absorber at (1). Weak aqua is introduced at the top of the absorber, ammonia as it passes counter flow through this unit. The hydrogen leaves the top of the absorber and flow through the heat exchanger on its way to the evaporator. The strong ammonia solution leaves the bottom of the absorber and flows into the generator at the lower right.

Heat is supplied at the generator, which separates and drive the ammonia vapour out of the solution at (2). This vapour would easily rise into the condenser, but some means of elevating the weak aqua so that it flows into the top of the absorber must be used. The principle of the bubble pump is applied here. The discharge tube from the generator is extended down below the liquid end in the generator. As the vapour ammonia bubbles form and rise, they carry slugs of weak ammonia solution with them up the discharge tube into the separating vessel. From here weak ammonia solution flows to the absorber to repeat the cycle and vapour flow to the air cooled condenser to be liquefied and then flows into the evaporator.

Note the U bends in the weak solution line to the absorber and in the liquid line to the evaporator. These inhibit the hydrogen from getting into the high side of the system. The absolute pressure in the condenser is about the same as in the evaporator. Since practically pure ammonia is in the condenser its vapour pressure is substantially equal to the total pressure at (3). In the evaporator the ammonia vapour pressure is much less and in accordance, with Dalton's law of partial pressures, is equal to the total pressure minus the partial pressure of hydrogen. Being at a pressure below saturation pressure, the ammonia readily vapourized in the evaporator and refrigerates.

Actually several refinements have been added to increase the efficiency and improve the performance. A liquid heat exchanger is used for the weak solution going to the generator. The analyzer and rectifier are added to remove the water vapour that may formed in the generator so that only ammonia vapour goes to the condenser. The condenser and evaporator each consist of two sections, to permit extending the condenser below the top of the evaporator and to segregate the freezing portion of the evaporator. A reserve hydrogen vessel is added to give the same efficient under variable load condition.

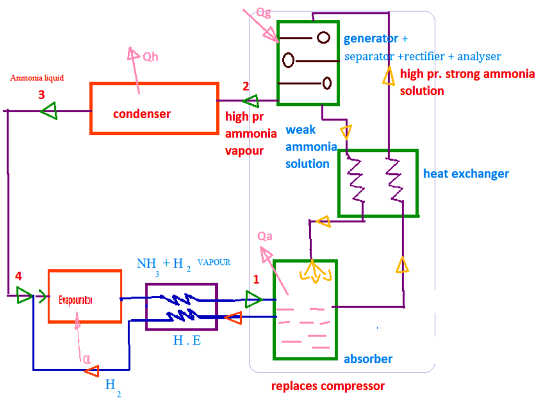

Fig. 1 Vapour absorption system

DESIGN OF GENERATOR AND HEAT EXCHANGER

Normally in the commercial vapour absorption system generator is the electrical heater which can be replaced by the heat exchanger to utilize the waste exhaust energy from the IC engine. So that the generator should designed based on the engine specifications. In this work, Assume capacity of refrigerator is 0.5 tones and cooling load is 1.75 kW.

$$Q_e = \dot{m}_{ref}\, h_{fg} \qquad (1)$$

Q_e = Cooling load kW

h_{fg} = latent heat of vapourization of the liquid refrigerant in the evaporator

$\dot{m}_{ref}$ = mass flow rate of refrigerant kg/s

From the above eqn. 1 mass flow rate of the refrigerant is 0.00131 kg/s. the exhaust gas has the heat capacity of 2.85 kW at the low load conditions and 9.663 kW at high load conditions and also exhaust heat energy at low load conditions itself enough to operate the system. Assuming the heat available in the exhaust is totally absorbed by the strong solution.

$$Q_g = Q_s$$

Q_g = Exhaust heat energy kW

Q_s = heat absorbed by the strong solution

Assuming temperature drop at the generator as 260 °C to 110 °C and the refrigerant temperature drop as 70 °C to 40 °C.

$$LMTD = \frac{(T_{g1} - T_{r1}) - (T_{g2} - T_{r2})}{\ln\frac{(T_{g1} - T_{r1})}{(T_{g2} - T_{r2})}} \qquad (2)$$

The logarithmic mean temperature difference is 120.17 °C and assuming the fouling factor for heat exchanger as 0.9. From the eqn. 3 number of tubes in the generator is evaluated.

$$Q_g = U\, A\, LMTD\, F \qquad (3)$$

Number of tubes in the generator is 28, for design of heat exchanger heat is transferred from weak

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solution to strong solution. From the design length of the tube is 3.584 m.

DISCUSSIONS

Following trend shows the variations of parameters like SFC, Exhaust gas flow rate, Exhaust gas temperature and Exhaust gas capacity. Fig. 2 shows the variation of specific fuel consumption with speed, it decreases with increase engine speed, torque and engine power output. Fig. 3 exhaust gas flow rate increases because of the total air consumption and fuel consumption gets increased with load conditions. Fig. 4 and Fig. 5 exhaust gas temperature and exhaust gas capacity increased because the power output increased so that the fuel consumption increases and so the heat input is higher and the exhaust energy is relative to the brake power

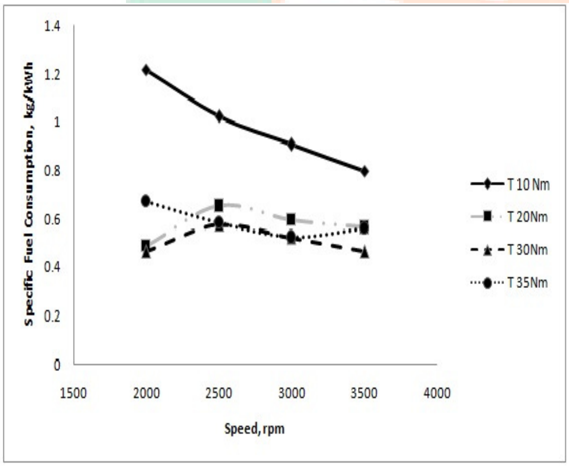

Fig. 2 Specific fuel consumption against engine speed

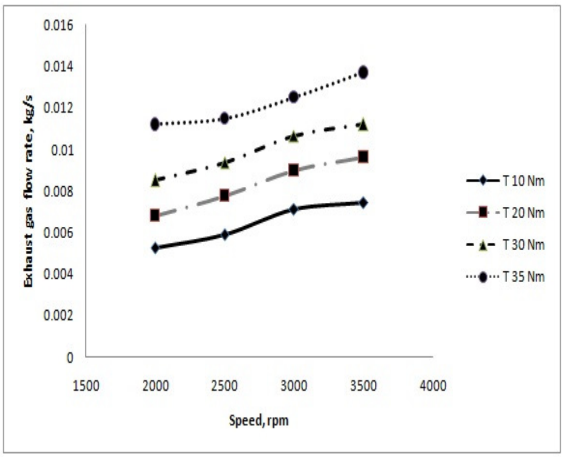

Fig. 3 Exhaust gas flow rate against engine speed

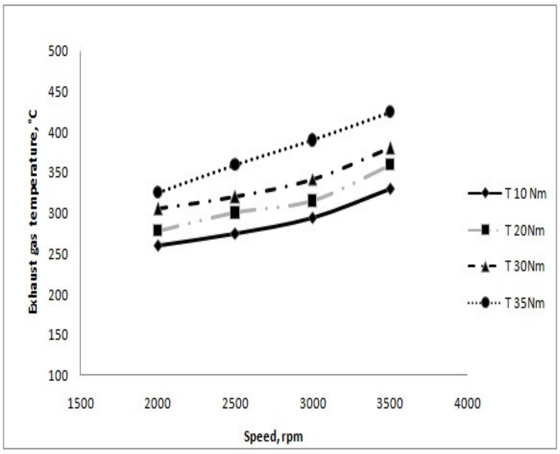

Fig. 4 Exhaust gas temperature against engine speed

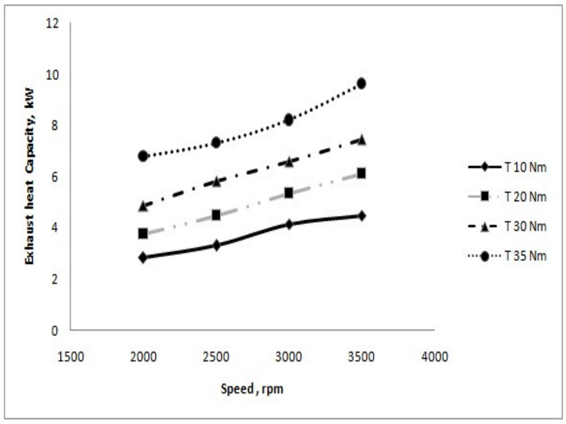

Fig. 5 Exhaust heat capacity against engine speed

CONCLUSIONS

The conclusions obtained from the work are:

- The exhaust gas heat capacity is enough to operate the vapour absorption system at low load and maximum load conditions and the temperature controller should installed to avoid mixing up of water vapour with refrigerant vapour at higher temperature condition (above 100 °C).
- The generator and heat exchanger design are carried out and assembled with the engine with necessary precautions because the implementing the generator at the exhaust will create the back

pressure and it will increases the work, fuel consumption and emission.

- On implementing in the on road automotive vehicle, emission may get affected by implementing vapour absorption system with the engine and so to avoid difficulties study must be carried about the control measures which reduces the emission.

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