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Waste Heat Recovery of 80 CC Petrol Engine for Refrigeration with VAC System

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ABSTRACT

Waste heat recovery is essential for achieving the fuel economy of engine indirectly. In this project vapor absorption refrigeration system is used to utilize the waste heat from engine. The use of recovered heat is made in generator of the vapor absorption system and due to this heat refrigerant gets separated from absorbent. This absorption system uses water as absorbent and R134a as refrigerant. This heat recovery system can be adopted in both traction and non-traction application of engine, in this system heat is recovered from the exhaust gases of engine by passing the exhaust pipe from the generator. In this paper the more focus is given to the design and manufacturing of the system with 80 cc internal combustion petrol engine.

Keywords — **R134a, water, generator, absorber, condenser**

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I. INTRODUCTION

In the vapour absorption refrigeration system, the mechanical process of vapour compression replaces with a physicochemical process by using energy in the form of heat. The vapour absorption refrigeration systems have many more favourable characteristics. Likewise a smaller electrical input is required to drive the solution pump, condenser fan also it is having fewer moving parts means less noise. In this system the compressor is replaced by an absorber, a pump and generator. These mounted components performed the same function as that of compressor used in vapour compression system. Generally $35^{\%}$ of thermal energy generated in the combustion process of engine is lost to the atmosphere through the exhaust gas and also dissipates from other parts. In this work one provision is made to recover the lost heat from exhaust gases. So here heat is recovered by passing the exhaust pipe from the generator of vapour absorption system. This system does not affect the design efficiency, life and fuel consumption of an engine, but it does add some weight. Utility cars are commonly equipped with refrigeration systems. Some have a vapour compression system powered by the engine via pulley and belt or by a battery unit. In most car engines, heat is removed through the radiator using a coolant and then rejected to the atmosphere. The other significant heat rejection way is through the exhaust system. Even In the case of turbo-charging or supercharging of high-performance engines the exhaust heat is used.[1-2]

A.Basic Absorption System

In the absorption refrigeration cycle, the low-pressure refrigerant (e.g. ammonia or H_2O) vapour from evaporator is absorbed in the absorbent (e.g. water or LiBr) and the resulted liquid strong solution in the absorber is pumped towards the generator by a liquid pump, little work input is required to pump the strong liquid solution. For the functioning of the system a source of heat with temperature ranging from 100 to 300^0C must be available. After generator rest functioning of the system is same as that of vaopur compression system. COPs for absorption systems are near to 1.There may be some safety related issues in transporting ammonia or lithium bromide in cars, which could cause significant restriction to absorption systems in the automobile industry. Another major disadvantage is that corrosion in the evaporator can occur. Lithium bromide is highly corrosive. So there is a need to develop a system which does not have any above mentioned haphazard effects. Hence to overcome the disadvantages of a Li-Br Absorption system new absorption system with R134a –H_2O is designed, developed and analyzed in this work.

B. Various Heat Recovery Technologies:-

1) *Metal Hydride Systems*

Metal hydride heat pumps implement the fact that when hydrogen is adsorbed by some metal alloys, heat is released because the execution of exothermic reaction. The process is reversible. In the equation below, M represents the earth metal alloy, and MH_x the metal hydride. [3]

$$M+\frac{x}{2}H_2 \text{ ------ } MH_X + Heat$$

In its simplest form of configuration the system could use two metal hydride beds a low temperature and high temperature metal, and three heat exchanger sections likewise high, ambient, and low temperatures. It cycles the beds through these heat exchangers over time to achieve cooling. Continuous cooling can be obtained by having four hydride beds. Metal hydride systems have fewer stationary parts and fewer moving parts than a conventional VCR system. This results in lower maintenance costs. They also requires a smaller volume and do not require chlorofluorocarbons (CFC) for cooling. A significant barrier to overcome before hydride cooling systems can be viable in a vehicle is its low coefficient of performance (COP), around 0.4, with maximum values of up to 2.5. Even at these low COPs, however, a large amount of cooling is available for the vehicle cabin. [3]

2) *Zeolite Systems*

This system is similar to metal hydride system, but here zeolite and water is used in place of a metal hydride and hydrogen.

$$Zeolite + H_2o \text{ ---- } ZeoliteH_2o + Heat$$

A zeolite system requires cycling between adsorption and desorption. The run of adsorption/desorption processes is reversible. The resulting cold source can be used for cooling and air conditioning while the simultaneously produced heat of adsorption within the zeolite tank can be used for heating. The adsorption process with zeolites is very strong, permitting high efficiencies for adsorption heat pump cycles with air-cooled condensers, COP is around 1.2. They also let heating and cooling at the same time. This might be useful, for example, to heat the catalyst for quick light-off, while cooling the cabin compartment for interior thermal comfort. One benefit of zeolite systems is that to provide continuous cooling, systems need to cycle between multiple sorption modules. [3]

3) *Thermo Acoustics Systems*

Thermo acoustic refrigerators use sound waves to transfer heat. A stack is utilized to keep the sound wave in location long enough for heat transfer to occur. This process appears attractive due to their reliability and low cost, also they are safe and have no moving parts. However, they have low efficiencies and low power density. This system is bulky and these is a major disadvantage.

4) *Active Magnetic Regenerator Systems*

This system is operated by using a magnetic component to magnetize and demagnetize a magnetic ‘refrigerant’, and a porous bed through which a heat transfer fluid flows. The major benefits of AMR technology relates to the lack of environmentally harmful refrigerants. Moreover, their efficiencies are higher than comparable VCR systems. The porous magnetic bed is solid, and the heat transfer medium is liquid, which can be moved with greater efficiency than gases. Mass and cost are two most limiting issues with AMR technology. The major difficulty with this system is that it affects the neighboring electric devices also it affects on the surrounding systems which contains ferrous material.

5) *Thermoelectric Devices*

In this conceptual system, electrical power is extracted from the hot exhaust gas by a Seebeck device which in turn is used to drive a Peltier thermoelectric air-conditioner. Peltier–Seebeck thermoelectric devices have highly desirable qualities for refrigeration in their scalability, adaptability, reliability and lack of refrigerants. The greatest deficiency with the use of Peltier thermoelectric devices is their poor thermal efficiency.

6) *Absorption Systems*

In this system the corrosion is a serious problem which may generate hydrogen gas that reduces the evaporator vacuum in which case the system would operate poorly. In addition, the debris resulting from the corrosion fouls could restrict narrow passages of the system. The well established use of absorption chillers for non-traction applications makes the proposed concept more charming than the rest, hence it has selected for further analysis and test as a subject of this project. Table 1 provides a simple comparison of the benefits offered by each alternative refrigeration system to VCR systems, in terms of cost to manufacture, coefficient of performance (COPr), total equivalent warming impact (TEWI) and weight.

TABLE 1
COMPARISON OF REFRIGERATION SYSTEMS

System	**Cost**	**COP**	**Weight**	**TEWI**
VC	OK	Good	Good	Poor
VAR	**Poor**	**Poor**	**Poor**	**Good**
Metal hydride	Very poor	Poor	OK	Good
Zeolite system	OK	OK	OK	Good
TA system	V.good	Poor	Good	Very good
AMR	Poor	Very good	Poor	Very good
TE	Good	Very poor	OK	-

II. DESIGN OF THE R134a - H_2O SYSTEM

System has been designed by considering below mentioned parameters.

1) Temperature at generator, $t_g = 90^0c$

2) Temperature at condenser, $t_c = 40^0c$

3) Temperature at evaporator, $t_e = 05^0c$

4) Temperature at absorber, $t_a = 25^0c$

A. Equations

1) Refrigerating effect $(R_E) = m_r \times h_{fg}$

2) $LMTD = \frac{[[t_s - t_i] - [t_s - t_0]]}{\ln[\frac{[t_s - t_i]}{[t_s - t_0]}]}$

3) $Gr = \frac{g.\beta.\rho^2 \Delta t.D_o^3}{\mu^2}$

4) $Q = M_r .C_p.(t_g - t) + M_r . h_{fg}$

5) $Q = UA\Delta T$

6) $Nu = \frac{h.D_o}{K}$

7) $L = \frac{Q}{h \times \pi D_i \times LMTD}$

8) $COP = (\frac{T_e}{T_c - T_e}) (\frac{T_g - T_c}{T_g})$

9) $\frac{m_a}{m_r} = \frac{X_b}{(X_a - X_b)}$

10) $V = \frac{m}{A\rho}$

Final dimensions of designed parts are

Generator	1) D_0 = 0.012 m
	2) D_i = 0.01 m
	3) L = 2.905 m
Condenser	1) D_0 = 0.012 m
	2) D_i = 0.01 m
Evaporator	1) Di = 0.01 m
	2) D_0 = 0.012 m
	3) L = 4.87 m
Absorber	1) D_o = 0.30 m
	2) L = 0.609 m

III. EXPERIMENTATION AND SETUP

A. Basic Components

In vapour absorption system, the function of the compressor is accomplished in a three step process by the use of the absorber, pump and generator, description of various parts are as follow:

1) Absorber:-

It is a device in which weak solution get converted into the strong solution by absorbing refrigerant vapour from evaporator. This absorption process results heat generation due to propagation of exothermic reaction and for the purpose of heat dissipation absorber is generally manufactured with larger surface area.

2) Pump:-

It does the pumping of strong solution towards the generator.

3) Generator or Desorber:-

It is a device in which distillation takes place and strong solution gets converted into weak solution. This distillation also result the driven-off of vapour from generator.

4) Condenser:-

Here latent heat of condensation is rejected to the atmosphere and gaseous refrigerant gets converted into the liquid phase.

5) Expansion Coil:-

Here expansion of refrigerant takes place and its pressure drop up to the condenser pressure. It is a device from itself refrigerant starts to evaporate.

6) Evaporator:-

Here refrigerant takes the latent heat of evaporation from surrounding and starts to evaporate.

Following figure shows the block diagram of experimental setup which reflects the working of the system.

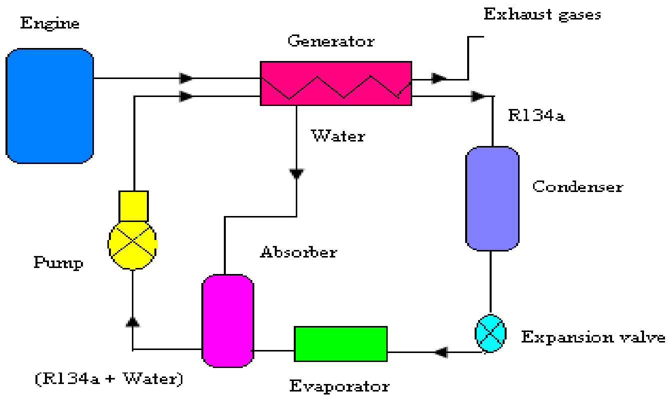

Fig 1 Block diagram of experimental setup

IV. EXPERIMENTAL PROCEDURE

Heat input is given to generator by starting engine. Temperature is measured at various points after achieving steady state. Pressure is also measured after generator and expansion coil. Engine speed is measured with tachometer and by measuring various necessary data COP is calculated at various ambient temperatures. Evaporator and condenser temperature is measured at various speeds of engine.

V. RESULT ANALYSIS

The effects of different engine parameters on the performance of refrigeration system have been investigated, these parameters are the engine speed, exhaust gases temperature and exhaust gas flow rates. The effect of the generator, condenser, absorber and evaporator temperatures on the capacity of refrigeration system has been observed. From the observation it is clear that as the engine speed increases the exhaust gases temperature and energy available will also increases as shown in figures 2 and 3.[5]

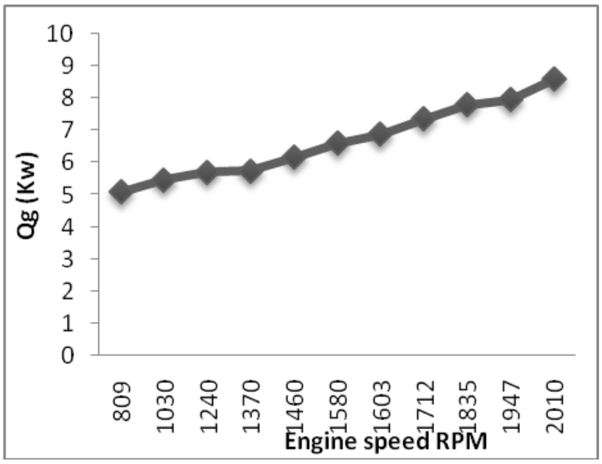

Fig 2.Effect of Engine speed on Exhaust heat generation (Q_g)

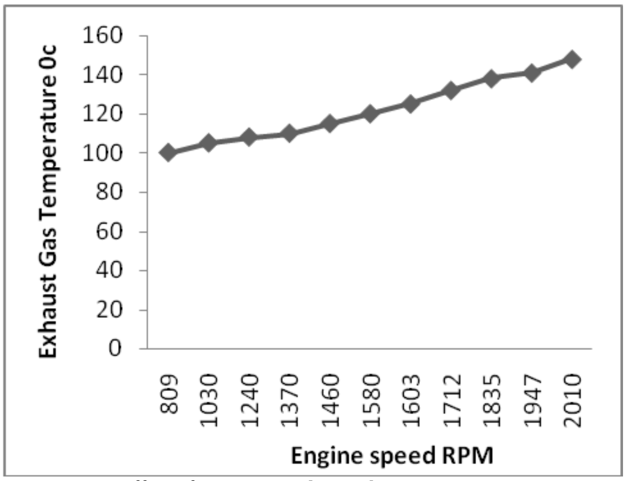

Fig 3.Effect of Engine speed on Exhaust gas temperature

Therefore absorption refrigeration system is able to take advantage of the exhaust gas heat and thus provides the cooling. Figure 4 shows the variation of COP with evaporator temperature for the generator temperature T_g = 90^0c and condenser T_C = 40^0c. After performing trial it is found that the COP increased slightly by increasing the evaporator temperature, this increment is due to the increment of enthalpies and hence increasing the capacity of the evaporator.[5]

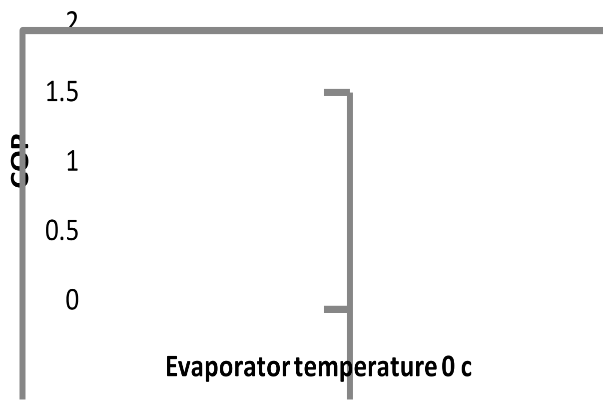

Fig 4. Variation of COP with Evaporator temperature

COP of the system also gets vary with the heat supplied to the generator and figure 5 shows the variation of the COP with heat supplied to the generator, from figure it is clear that COP of the system get increases with decrease in the heat input to the generator.[5]

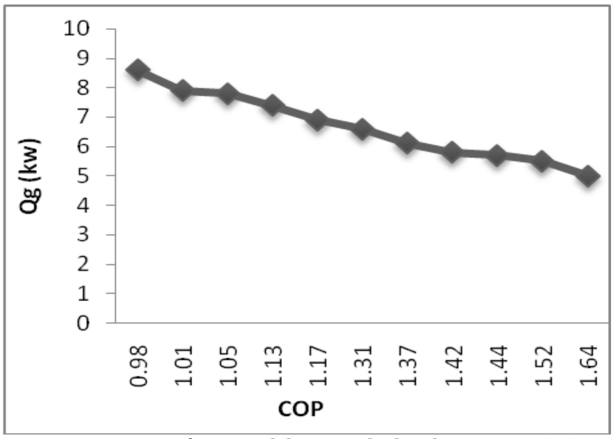

Fig 5. Variation of COP with heat supplied to the generator (Q_g)

VI. CONCLUSION

The waste heat recovery system has been analyzed and experimentally investigated in this article. In this paper work has been supported by a suitable mathematical model .The study reveals that it comprises two heat exchangers, namely: air forced convection condenser, air forced convection evaporator and absorber, an expansion valve. The exhaust gas from an 80 cc internal combustion engine was used to run a 0.5 TR vapour absorption system which was designed for hot gas intake. The experiments conducted on the system, prove that the concept is feasible and could be used for refrigeration in traction and non-traction application of engine. The absorption system is having few high precision components, thus it reduces manufacturing costs. This system is having some silent features like high reliability, low maintenance, flexibility in operation and less noise.

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