Analysis of Waste Heat Driven Air Conditioning System for Automobile

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Abstract- *Existing automobile engine losses lots of heat through exhaust gas. In this vapour absorption system exhaust heat is used as heating source of vapour absorption system. From the literature it is observed that heat potential is sufficient for powering the proposed air conditioning system. The significance of the work is that it will provide space cooling for the passengers and thereby enhances thermal efficiency and reduces fuel consumption without affecting performance of the automobile. Further the vapour absorption cycle uses non CFC refrigerant and thereby have no effect on environment. The present work is focused towards the design and development of an air conditioning system for the automobile using waste heat from exhaust. Also this system includes control system which varies the flow rate of solution in generator according to engine exhaust gas temperature as it varies according to load condition. Also, this research work includes study of thermodynamic and parametric analysis of Li-Br vapour absorption refrigeration system.*

Keywords- control system, heat potential, Li-Br vapour absorber, non CFC refrigerant, thermal efficiency etc.

I. INTRODUCTION

Since 1987 the Montreal Protocol controls the use and release of CFCs and has set a time scale schedule for eliminating their production. This agreement is an historic step in the ongoing process of building consensus regarding environmental impacts of CFCs. One of the HCFCs, R-22, and one of the HFCs, R-134a, are utilized as substitutes for CFCs, but the HCFCs and HFCs will face similar restriction for their high GWP (Global Warming Potential). For comparison, some of the working fluids ODP and GWP are listed in Table 1.1[1].

Nowadays, almost all car air-conditioning systems are charged with R-134a. However, alternatives with lower GWP than R-134a are desirable. Some new systems are being developed in order to revitalize the use of ecologically safe refrigerants. For example, a system for car air-conditioning using CO_2 as the refrigerant has been developed by Lorentzen and Pettersen (1993). The testing of a laboratory prototype has shown that CO_2 is an acceptable refrigerant for car air-conditioners. Due to the international attempt to find alternative energies, absorption refrigeration has become a prime system for many cooling applications. Where thermal energy is available the absorption refrigerator can very well substitute the vapour compression system.

Table 1:Ozone depletion and global warming potential

Chemical	ODP	GWP	Estimated Atmospheric Life (Years)
Water H_2O	0.93	3700	122
HCFC-22 $CHClF_2$	0.05	510	18
HFC-134a CF_3CH_2F	0	400	18
Carbon dioxide CO_2	0	10	230
Ammonia NH_3	0	0	-
CFC-12 CCl_2F_2	0	0	-

It is a well-known fact that a large amount of heat energy associated with the exhaust gases from an engine is wasted. A rough energy balance of the available energy in the combustion of fuel in a motor car engine shows that one third is converted into shaft work, one third is lost at the radiator and one third is wasted as heat at the exhaust system [1]. Even for a relative small car-engine, such as for the Nissan1400, 15 kW of heat energy can be utilized from the exhaust gas [2]. This heat is enough to power an absorption refrigeration system to produce a refrigeration capacity of 5 kW.

In current automobile air conditioning system i.e. vapour compression system, compressor is coupled to engine which increase the load and also consumes the more fuel. That is why vapour compression system should be replaced by vapour absorption system which drives over a waste heat exhausted by engine reducing extra load of it.

II. RESEARCH ELABORATION

Calculation of the waste heat present in automobile exhaust in SI or CI engine. For this purpose thermocouple and rotameter is used.

Determination the cooling capacity required by considering cooling load by internal area of car without glass surface, cooling load by glass exposed to that atmosphere and cooling load by living body.

Carry the feasibility test and examine whether the proposed system is feasible or not by comparing literature and above analysis.

Optimization the design of every component of system and study the various parameters and their effect on system performance. For this purpose mini channel condenser and mini channel evaporator are used to replace condenser and evaporator respectively.

Designing the Control system with respect to control flow rate to the generator. This system is used for proper utilization of waste heat energy.

Manufacturing the absorption system and control system suitable for automobile which can replace vapour compression system.

Experimentation on varying load condition. These experimental values are useful for actual demonstration of automobile.

Comparison of the result.

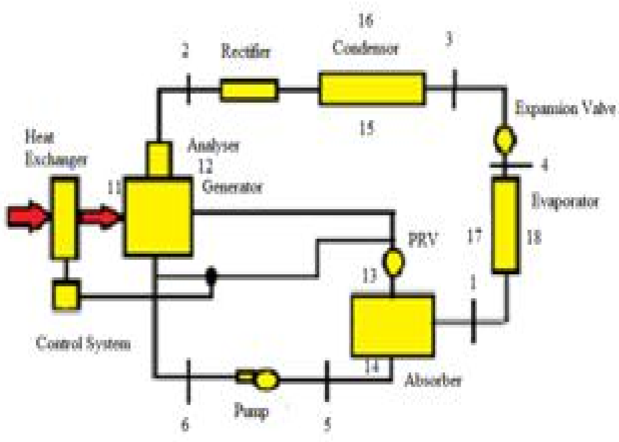

Figure 1: Experimental Setup

III. DESIGN ANALYSIS

A) Cooling Load Estimation

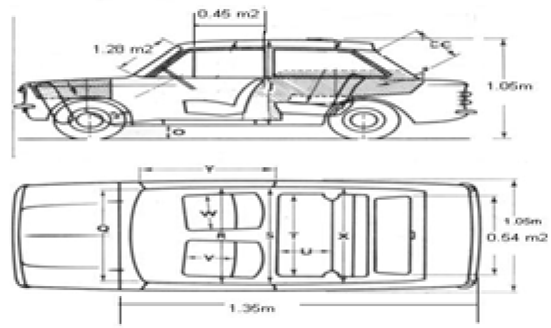

Figure 2: Surface area of car body

Let,

L= length of car body, m
W= width of car body, m
H= height of car body, m
A= side of glass
W_f, L_f= width and length of front glass
W_r, L_r= width and length of rear glass

Calculation of surface area

1) 2(L+W) =4.8m^2
2) 2(W+H) =4.2m^2
3) 2(L+H) =4.8m^2

Calculation of glass area

$4*(A)^2$=0.81 m^2
Front glass calculation
L_f*W_f=1.28m^2
Rear glass calculation
L_r*W_r=0.54m^2

Total internal surface area of car without glass
Surface area=Total area-total glass area
Surface area= 13.8-2.63 = 11.17m^2

According to ASHRAE handbook chapter 4, while calculating the cooling load it mainly consist three parameters. Cooling load by considering internal area of car without considering glass surface, cooling load by glass exposed to the atmosphere and cooling load by living body.

Consider body of car made up two layers aluminum and fiber. Thermal conductivity of aluminum is 0.055 w/mkand fiber is 0.06 w/mk.

Therefore cooling load is,

$$Q=\Delta T1/\frac{1}{h1A1}+\Delta T2/\frac{x1}{k1A1}+\Delta t3/\frac{x2}{k2A2}+\Delta T4/\frac{1}{h2A2}$$

Q = 2.02177 KW

Cooling load for exposed glass to that atmosphere,

$Q_{glass} = \Delta T1/\frac{1}{h1A2} + \Delta T1/\frac{x}{kA2} + \Delta T1/\frac{1}{h2A2}$

$Q_{glass} = 0.137KW$

Metabolic load consider to taking in account one driver and three passenger to calculate the heat in the cabinet due to human metabolism

Consider M for driver 85 W/m^2 and for passenger M is 55 W/m^2, Weight of persons is 60 kg and height is to be 1.85m.

$Q_{met}=\sum_{passenger} MA_{Du}$
Where $A_{Du}=0.202w^{0.425} * H^{0.725}$
$A_{Du}=1.7979m^2$
$Q_{met}=449.47W$

Considering radiation heat load through glasses of car body,
$Q_{rad}=\sum_{Surface} S*\tau*i_{Dir}*\cos\Theta$
$Q_{rad}=60$ W
Now total cooling load,

$Q_{total} = Q + Q_{glass}+Q_{met}+Q_{rad}$
$Q_{total} = 2.02177+0.137+0.44947+0.060$
$Q_{total} = 2.66824$ KW

B) Load Analysis of Component

Energy Analysis of each component of 1.7585 KW aqueous lithium bromide absorption systems is introduced in following section:-
Assumption taken:-

1. Condenser temperature =35°C.
2. Evaporation temperature =7°C.
3. Absorber temperature=37°C.
4. Generator temperature=85°C.

1) Generator

a) Energy Balance on the solution side and heat source $Q_{gen}=m_2h_2+m_8h_8-m_7h_7 = m_{11} *(h_{11}-h_{12})$
b) Log Mean Temperature Difference
$LMTD_{gen} = \frac{(T11-T8)-(T12-T2)}{\ln\left(\frac{T11-T8}{T12-T2}\right)}$
c) Mass and Salt should balance to satisfy the conservation law
$m_7 = m_2+m_8$; $m_7 x_7 = m_8 x_8$
d) Heat Transfer Rate
$Q_{gen}= U* A_{gen}*LMTD_{gen}$

Above same procedure are to be followed for the other parameters below

- Condenser
- Evaporator
- Absorber
- Solution heat exchanger

IV. RESULTS

From theoretical calculation and COOLPACK Analysis following result table is tabulated

Table 2: Component Analysis Table

Sr. No.	Parameters	Theoretical Values	Values By COOLPACK Analysis
1.	Generator Load	2.725 kw	-
2.	Condenser Load	2.113 kw	2.129 kw
3.	Evaporator Load	1.758 kw	1.759 kw
4.	Absorber Load	2.567 kw	-
5.	Solution Heat Exchanger	0.416 kw	-
6.	System Efficiency	65%	65%

V. CONCLUSION

The theoretical calculations shows cooling load is around 2.5 kW while engine exhaust can produce cooling affect around 3 kW. This clearly shows the feasibility of the proposed system. Also proposed vapour absorption system use non CFC refrigerant and thereby have no effect on environment. Also it includes control system which varies the flow rate of solution in generator according to engine exhaust gas temperature as it varies according to load condition. Also it found that theoretical load of condenser and evaporator is nearly same to cool pack analysis software.

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APPENDIX