Design and Development of Small Scale VAR System by Using Exhaust Gas of IC Engine

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Abstract - *Vehicles uses the technology of vapor compression system for air conditioning the car cabin. Huge amount of heat energy with the exhaust gases from an engine are wasted. An energy balance sheet of the accessible energy in the combustion of fuel in a 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. Exhaust gas energy of an IC engine can be used to power a vapor absorption refrigeration system for air-conditioning the car cabin. Hence there will be reduced amount of load on the engine to run compressor, so pollution can be reduced up to 15%.*

Key Words: Car air conditioning, Vapor compression refrigeration system, Waste heat of car exhaust, Vapor absorption refrigeration system, Car Heat Load.

1. INTRODUCTION

The major difficulty to overcome the development of internal combustion engine is the reduction of emissions it is achieved by increasing the engine efficiency and this can be achieved by using waste heat of exhaust gases. The recovery of waste energy or waste heat recovery is heat, which is produced in a process by way of fuel combustion or chemical reaction and then dumped into the environment even through it could still be reused for some useful and financial resolution. For such cases, vapor compression air conditioning system is used for cooling the cabin and in goods carrying. Internal combustion engine efficiency can be increased by attaching absorption refrigeration system. A generator is a unit of Vapor absorption refrigeration system which recovers heat from the exhaust gases of the IC engine and reduces the temperature and emissions as well. With help of waste heat energy, the coefficient of performance is increased to 23% and it is estimated that recovery of waste heat reduces heat lose and improves performance of system. The heat released to exhaust gases can be between 150-400℃. This source of heat and high mass flow rate of exhaust gases are the most suitable source of running and working the generator of Vapor absorption refrigeration system. From past few decades, aqua-ammonia is one of the widely used refrigerants due its high latent heat of vaporization and a small specific volume of liquid refrigerant. The combination of aqua-ammonia is better than the fluorocarbon refrigerant as refrigerants used in absorption system because it is free from the limitations of high freezing temperature of the refrigerant and low crystallization temperature of the solution. ammonia based refrigerant systems cost up to 10-20% less than one that uses CFCs because of using narrower diameter pipes. Hence, ammonia is affordable than CFCs and HFCs.

2. LITERATURE REVIEW

Optimum design of car air conditioning has always been in limelight of automotive manufacturers and academic researchers during the last few decades. Two crucial targets for the auto industry are to improve the efficiency are diminution of fuel consumption and tailpipe emission.

Isaac Mathew Pavoodath, [1] investigated that adsorption refrigeration systems contains many benefits besides environment friendly refrigerants as well as electricity savings. Briefly, they are: simplicity, low maintenance, and high temperature heat input capability, less pump power, inherent flexibility in operation, with a system performance insensitive to ambient temperature. Reddy et. al, [2] has suggested that exhaust gases can be used as an alternative energy source to run the air conditioning system in cars. They have carried out experiments and have obtained that heat available at exhaust gas is 5.5 kw and heat carried by cooling water is 12.54 kw. Vapor absorption refrigeration system is undoubtly an attractive substance that utilizes the waste heat from CI engine. For the present research, a vapor absorption system associated with waste heat repossession from four stroke diesel engine is used to find out the coefficient of performance and energy consumption and the energy consumption of 220 kJ/K is saved than the existing system. S Wang, [3] designed, simulated and validated the prototype, preliminary analysis (Wang, 1997) presented that a absorption refrigeration plant with a 2 kW cooling load at 0°C and with water as a secondary fluid, is more than sufficient to air-condition the passenger void of the Nissan 1400 truck. In the exhaust gases of motor vehicles, there is enough heat energy that can be used to power an air-conditioning system. Thus, if air-conditioning is achieved without using the engine's mechanical output, there will be a net reduction in fuel consumption and emissions. S.G. Kandelkar, [4] analyzed the performance of an ideal and a practical absorber heat recovery cycle is calculated from the above analysis using a computer. The variation of cop with generator temperature two values for 30°c and 45°c for absorber and condenser temperatures are choosing to represent water and cooled systems. The most values of cop are 0.705 and 0.555 for water and air-cooled practical absorber heat recovery cycles, respectively. The most of cop value occurs at generator temperatures between 110-120°c for a water-cooled practical cycle, while for an air-cooled practical cycle, the optimum cop value is obtained 140°c-170°c. It's undoubtly clear that for air-cooled systems with their higher heat rejection temperature, the cop values are lesser than those corresponding to water-cooled systems. N. D. Shirgire et. al., [5] It is computed that the heat transfer in helical circular tubes is way more compared to straight tube due to their shape. Helical coils are certainly beneficial over straight tubes due to their less shape, size and increased heat transfer coefficient. Due to curvature of the coil it produces the centrifugal force while the pitch (or helix angle) influences the torsion to which the fluid is subjected to. The outgrowth of secondary flow is resulted by the centrifugal force. M A Lambert et. al, [6] Crucially designed the criteria for the absorber are the amount of refrigerant required to run the desired cycle, which is based on hevap for nh3, and the amount of adsorbent required to adsorb and desorb the ammonia at a feasible rate. Cooling down a car that has been sitting in the sun for several hours (called 'hot soaking') to a comfortable temperature nominally requires q˙cool=5–7 kw of cooling for 10 min. Whenever the cabin is cool, about one-third of full capacity or q˙ cool=1.7–2.3 kw is required to maintain cabin comfort, depending upon thermostat setting and ambient temperature and humidity.

3. EXPERIMENT AND HEAT LOAD CALCULATIONS

An experiment was conducted on 4-cylinder 4 stroke diesel engine of 1400cc. The different loading on which the engine was tested is 0-22 kg. The temperature of exhaust from 0 to 22 kg is 85℃ to 223℃.

Table -1: Results of Experiment on I.C Engine

Sr.No	Mano-meter H_1	Mano-meter H_2	Speed N RPM	Time for 10 cc of fuel t_1 sec
1	105	120	1350	29.36
2	107	122	1350	25.58
3	105	120	1350	24.79
4	103	111	1350	15.78
5	99	110	1350	12.19

Sr.No	Spring Balance W kg	Time for 5 litre of water t_2 sec	Inlet Temp T_1	Exhaust Temp T_4
1	0	52	29	85
2	2	52	29	95
3	6.5	52	30	105
4	16.5	52	30	152
5	22.0	52	30	223

Heat carried away by exhaust gases:

$H_e = \{M_e \times C_{pg} \times (T4\text{-}T1)\}$ kJ/min
$= (M_a + TFC) \times CPG \times (T4 - T1)$
$= \{(79.42+1.08) \times 1.005 \times (105\text{-}30)\}/60$
$= 101.12$ kJ/min

M_e = Mass flow of exhaust gases in kg/min
C_{pg} = Specific heat of exhaust gases in kJ/kg.K
T_4 = Exhaust gas temperature in °C
T_1 = Room temperature in °C

Heat Load Calculations [7]

The vehicle is assumed to be driving approximately towards south. It's assumed that cooling load calculation is done in the month of May 15.

Cooling load is estimated for the transient period from 10.00 am to 4.00 pm. The cooling capacity needed to satisfy the cooling load in the tested vehicles cabin room under warm weather conditions which is not in the comfort level of 23° C.

The heat gain in the cabin due to metabolic load is constant due to no change in the number of passengers. The direct and diffuse radiation loads is another positive load. The direct loads have a greater contribution than diffuse or reflected load.

The direct and diffuse radiation load increases due to the increase in the sun altitude angle. The table below gives the overall load acting on the vehicle cabin.

Table -2: Heat Load Calculations

Time	Q_{Met}	Q_{Direct}	$Q_{Diffuse}$	Q_{Amb}	Q_{Ven}	Q_{AC}	Q_{Total}
10:00 AM	487	992.9	140.5	-120	-464	-3190.5	-2154.3
10:30 AM	487	947.1	141.7	-119	460.1	-3151	-2154.3
11:00 AM	487	777.7	142.6	-117	-454	-2990.3	-2154.3
11:30 AM	487	852.8	143.2	-116	-449	3071.7	-2154.3
12:00 PM	487	855.8	171.5	-115	-444	-3109.8	-2154.3
12:30 PM	487	852.3	143.2	-113	-439	-3084.4	-2154.3
13:00 PM	487	775.6	142.6	-112	-434	-3013.4	-2154.3

13:30 PM	487	946.3	141.6	-111	428.8	-3189.4	-2154.3
14:00 PM	487	987.2	139.7	-112	-434	-3222.1	-2154.3
14:30 PM	487	976.6	137.5	-113	-439	-3202.9	-2154.3
15:00 PM	487	935.4	134	-115	443.9	-3151.8	-2154.3
15:30 PM	487	866.2	129.3	-116	449	-3071.6	-2154.3
16:00 PM	487	866.1	143.7	-117	454	-3079.6	-2154.3

4. COMPONENT SPECIFICATION AND EXPERIMENTAL SET UP

4.1 3-D Modelling & Experimental Set Up

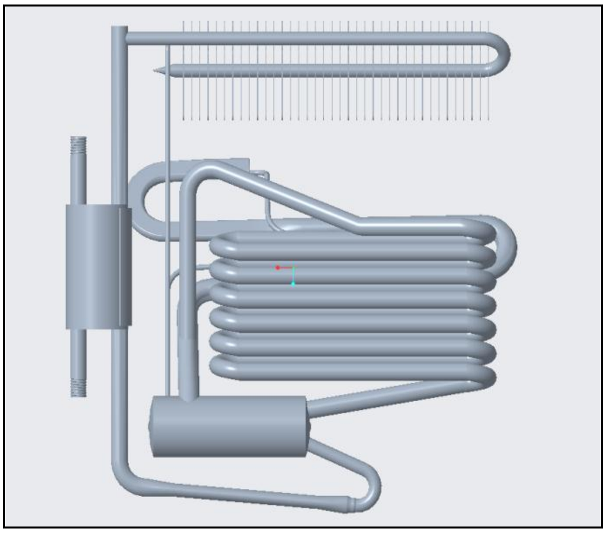

Fig -1: Front View

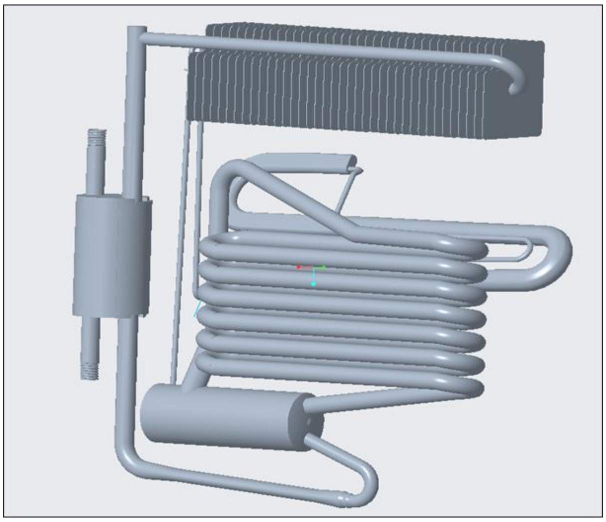

Fig -2: 3D Modelling

Fig -3: Experimental Set Up

4.2 Components Specification

Table -3: Components Specification

Components	Specifications
Heat Exchanger	Inlet pipe:- 0.75*3 inches
	Outlet pipe:- 0.75*3 inches
	Hollow section:- 3*5 inches
	Distance between baffles:- 1 inch
	Total length :- 11 inches
	Material:- M.S.
Condenser	Pipe dia:- 15 mm
	No. of fins:- 38
	Length:- 430 mm
	Material:- M.S.
Evaporator	Pipe dia:- 22 mm
	Material:- M.S.
Expansion Device	Pipe dia:- 6 mm
	Material:- M.S.
Absorber	Length:- 180 mm
	Diameter:- 68 mm
	Material:- M.S.
Cabin Space	0.086 cubic meter (86 litres)
Fan	80*80 mm of DC 12 voltage.
Armor Foam Sheet	Thermal conductivity:- 0.02 W/m.k
Glasswool	Thermal conductivity:- 0.02 W/m.k
Frame	Length:- 17 inches.
	Height:- 32 inches.
	Material:- M.S.

4.3 Results

It is measured that, when we are giving heat of exhaust gases from engine of approx. 90°C to our system, we are getting the temperature of 9°C on the evaporator pipe. Due to blower, the cabin is getting cooled and finally we get 29°C temperature inside the cabin (0.086 m^3 (86 litres)) whereas, the outside temperature is around 44°C.

Table -4: Results

Sr. No.	Engine Load Kg	Exhaust Gas Temp °C	Generator Temp °C	Evaporator Temp °C	Cabin Temp °C
1.	0	95	90	9.1	29
2.	6.5	120	110	8	23.2

5. CONCLUSION

- The possibility of exploiting waste heat from the industries has been of great significance in view of ever-increasing energy demand and environmental constraints.
- To recapitulate, making small scale VAR system is very tough task and specially operating it with the exhaust gases but, we managed to make it and finally we are getting the cooling effect inside the cabin.
- Overall, our main task was to run the system with the exhaust gases and generating air conditioning effect and we got the temperature of 29°C inside the cabin.
- We were getting around 7°C temperature at the evaporator pipe when the temperature of the generator pipe reached around 100°C.
- Finally, the usage of VAR system is very rare and people do not adopt it very easily but, we were able to make it on small scale and achieved cooling of 29°C in the cabin space.

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BIOGRAPHIES

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