Design And Analysis of Automobile Air Conditioning System Based on An Absorption Refrigeration Cycle Using Energy From Exhaust Gas of An Internal Combustion Engine

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Abstract- *It is a well-known fact that a lot of heat energy associated with the exhaust gases from an engine is wasted. IC engine has an efficiency of about 35-40%, which means that only one-third of the energy in the fuel is converted into useful work and about 60-65% is wasted to environment. In which about 28-30% is lost by cooling water and lubrication losses, around 30-32% is lost in the form of exhaust gases and remaining by radiation, etc. In this air conditioning System, a physicochemical process replaces the mechanical process of the Vapour Compression System by using energy in the form of heat rather than mechanical work. The heat required for running this type of air conditioning System can be obtained from that which is wasted into the atmosphere from an IC engine. The work described in this project attempts to use the energy from the automobile exhaust gases to power an air conditioning system. Thus the waste heat can be utilised and shaft power conserved by replacing the traditional compression refrigeration system, used for air-conditioning a automobile, with an absorption unit In this design of special components for getting air conditioning effect with the help of exhaust gas. The cop and air conditioning effect is calculated.*

Keywords- air conditioning, exhaust gas, COP, waste heat.

I. INTRODUCTION

Air conditioning is the process of removing heat from an enclosed or controlled space or from a substance and moving it to a place where it is unobjectionable. The primary purpose of air conditioning is lowering the temperature of the enclosed space or substance and then maintaining that lower temperature as compared to the surroundings. Cold is the absence of heat, hence in order to decrease a temperature, one should "remove heat", rather than "adding cold." The basic objective of developing a vapour absorption refrigerant system for cars is to cool the space inside the car by utilizing waste heat and exhaust gases from engine. The air conditioning system of cars in today’s world uses “Vapour Compression Refrigerant System” (VCRS) which absorbs and removes heat from the interior of the car which is the space to be cooled and further rejects the heat to be elsewhere. Now to increase an efficiency of car beyond a certain limit vapour compression refrigerant system resists it as it cannot make use of the exhaust gases from the engine. In vapour compression refrigerant system, the system utilizes power from engine shaft as the input power to drive the compressor of the refrigerant system. Hence the engine has to produce extra work to run the compressor of the air conditioning system thus utilizing extra amount of fuel. This loss of power of the vehicle for air conditioning can be neglected by implementing this type of air conditioning system.

As early as 1824, Michael Faraday accidentally discovered the principle of absorption refrigeration **[1]** in an attempt to demonstrate that some gases which were considered to be "ideal gases" could in fact be liquefied. Faraday exposed silver chloride crystals, a white powder, to dry ammonia gas.

When the powder became saturated with the gas, he sealed the ammonia-silver chloride compound in a test tube that was bent to form an inverted "V". He proceeded to heat the end of the tube that contained the compound while at the same time he was cooling the opposite end of the tube with cold water. The ammonia was released from the compound and condensed into liquid by the cold water. When this was accomplished Faraday removed the flame and cold water from underneath the tube, thinking that the experiment of liquefaction of a gas was over. After a few moments, Faraday observed a ·most unusual occurrence. The liquid ammonia was boiling and changing back into vapour, taking the heat from its immediate environment, which was the test tube itself and the surrounding air,thus producing intense cold. The vapour was reabsorbed by the silver chloridecrystals releasing heat.

II. VAPOUR ABSORPTION CYCLE

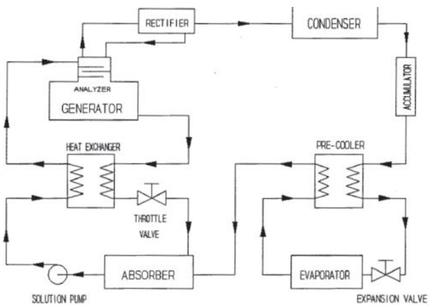

Figure 1 schematic view of a vapour absorption system

Heat is applied to the generator, which contains a solution rich in ammonia, strong solution. The ammonia vapour is driven off from the strong solution together with some water vapour. This vapour mixture is purified in the analyser and rectifier, where the water content of vapour is removed and returned to the generator in the form of a reflux solution.

The purified ammonia vapour condenses in the water or air cooled condenser. The condensate is cooled further in the pre-cooler before entering the expansion valve. After the expansion valve the liquid ammonia mixture enters the evaporator where it vaporises at low pressure and temperature. The ammonia vapour is fed into the absorber and combines with the weak solution from the generator. In the absorber, as the weak solution absorbs the ammoniavapour, considerable heat is liberated, which has to be removed to allow absorption to continue.

The strong solution that was formed in the absorber is pumped back into the generator by the solution pump. On its way, fr receives heat from the weak solution that flows from the generator on its way to the absorber. This is an advantageous feature in the system, as it permits a substantial reduction in heat input requirements and saves appreciably on the cooling required by the absorber.

III. EXPERIMENTAL SETUP

When the engine is started the exhaust gas coming from the engine went to the connected air conditioning equipment pipe and both the pipes are jointed with the help of copper tubes so the heat not going outside. Then that heat went to the absorber and aqua ammonia turns into vapour state and then that vapour state ammonia entering into condenser through the pipes. Then the ammonia is cooled and then the cooled ammonia entered into evaporator and the cooling effect is produced in the evaporator. The entire experimental setup will be shown in below figure.


Figure 2 Experimental setup

3.1 MAIN COMPONENTS OF THE SETUP

3.1.1 AIR CONDITIONING EQUIPMENT:

Fig below is the air condition equipment for our project. For air condition effect we need generator, condenser, absorber, evaporator. That all the components are manufactured and fitted in one equipment that equipment is called air condition equipment. The parts of air condition equipment are explained below


Figure 3 Air conditioning equipment

3.1.2 Generator

In an absorption refrigeration system, the generator is much like a boiler, where the heat energy is added to the system from an external source to the strong solution, which boils at high pressure releasing its vapour.

Figure 4 Generator

3.1.3 Condenser

In this the condenser is to cool the ammonia and reduce the pressure of the ammonia and gives reduced temperature of ammonia to evaporator. The following figure shows the condenser.

Figure 5 condenser

3.1.3 Evaporator

The evaporator is to get the cooling effect of the equipment. In this the cooled ammonia is coming from condenser and that ammonia is again cooled and the cooling effect is produced. The foolowing figure shows the evaporator box.

Figure 6 The evaporator

3.1.4 ABSORBOR

In this ammonia and water mixer is there when heat of the exhaust gas is touched the absorber then that aqua ammonia is transfer into vapour state and then that ammonia is entered into condensor pipe. The following figure shows the absorber.

Figure 7 Absorber

IV. SPECIFICATIONS OF ENGINE

The IC engine based on which the calculations are done is
No of cylinders, n = 1.
Power, P = 7 BHP at 1400 rpm.
Capacity, V = 100cc.
No of strokes = 4.
Fuel used = petrol
Air-fuel ratio, A/F =15:1

A. Waste Heat of the Engine

The two main areas through which the heat is exhausted into the atmosphere from the engine are the cooling water and the exhaust gases. It isnecessary to calculate the amount of heat energy carried away by the exhaust gases and the cooling water.

1) Exhaust gas heat: Volumetric efficiency of the engine,E_{vol}= 70%.

Rated speed, N = 1400rpm
Mass flow rate of air into the cylinder, m_a= VN E_{voi}/2 = (0.001x1400x0.7)/2, m_a=0.049m3/s.
Mass flow rate of fuel, m_f= m_a/(A/F ratio) = 0.049/15 =0.00326 kg/sec
Total mass flow rate of exhaust gas, m_e=m_a+m_f= 0.049+0.00326=0.05226 kg/s.
Specific heat at constant volume of exhaust gasC_{pe}= lkj/kgk.
Temperature available at the engine exhaust, t_e= 150°C.
Temperature of the ambientair, t_a= 40°C

Heat available at exhaust pipe,
Q_e= m**e** *$C_{pe}(t_e-t_a)$ = 0.05226xlx (150-40) =5.749Kw
The performance of the vapour absorption refrigeration system is given by the following formula
Coefficient of Performance (COP) = $[(T_e/T_c-T_e)*T_g–T_a/T_g]$
Where T_e=evaporator temperature
T_c=condenser temperature
T_g= generator temperature

2) Time required: The heat energy available at exhaust is. 5.749KW = 5.749 KJ/s

From the company specifications of the Electrolux system
Power required at the generator is (P_{actual}) = 480 W
So one minute of heating gives 5.749 x 60 = 344.94 KJ of energy.
This implies that by supply of waste heat for about 1mins, 330KJ of energy can be produced. This is more than sufficient to releaseone mole of ammonia vapour from the solution.

3) Mass of ammonia in solution

Molar concentration of saturated ammonium hydroxide = 17 mol/ l
Molecular mass of ammonia = 17 g/mol
Concentration of ammonia in one liter of solution = 17 x 17 =289 g/l
Volume of ammonium hydroxide solution = 0.7litres
Mass of ammonia in the solution = 289 x 0.7= 202.3 g

B. Cooling load calculation

The propose of load estimation is to determine the size of the refrigeration equipment that is required to maintain the designconditions during the periods of maximum outside temperatures. The design load is based on inside and outside design conditionsand it is in refrigeration equipment capacity to produce and maintain satisfactory condition.
Enthalpy change in generator,
Q_G = mass x latent heat of vapourisation
= 0.2023 x 1315.5KJ/Kg =266.125 KJ
This is the amount of energy absorbed at the generator to liberate ammonia vapour from solution.

C. Theoretical temperature drop

Assuming the fridge is empty with only air inside to obtain the max temperature drop
Volume of cooling cabin = 23 liters
Hence volume of air inside the cabin = 0.023m3
Density of air = 1.15 Kg/m3 (at sea level, 30°C)
Mass of air inside the cabin = 0.02645 Kg
Specific heat of air (*cp*) =1.005 kJ/kg K
Assuming ambient temperature (T_{amb}) = 40°C
= 313 K
Enthalpy change of refrigerant during evaporation = Enthalpy change of air inside cabin
+ Enthalpy change of ammonia vapour
Assuming a theoretical COP of 0.1
COP = QE /QG
QE = 0.1 x 266.125=26.125 KJ
This much energy is absorbed from the evaporator cabin
QE = m_{air}x c_px change in temperature
26.125 = 0.02645x 1.005 x (313 - T_e) + 202.3 x 4.75 x (313 - Te)
Te = 295.71 K =22.71°C
This is the theoretical temperature drop which can be obtained from the modified system

D. Experimental procedure

The COP of this air conditioning equipment is also calculated by with the help of generator, condenser, absorber, evaporator temperature. The different temperatures of different components are taken and the cop of the system will be calculated.

T_g(°k)	T_a (°k)	T_c(°k)	T_e(°k)	COP
393	343	313	295	2.035
383	342	312	294.6	2.015
373	341.5	311	294.3	2.001
363	341.2	311.5	293.8	1.992

V. CONCLUSION

The following are conclusions for the experiment

1. In the exhaust gases of motor vehicles, there is enough heat energy which can be utilised to power an air-conditioning system "free" from any energy requirements.
2. Once a secondary fluid such as water is used, the aqua-ammonia absorbent-refrigerant combination appears to be a good candidate as a working fluid for an absorption refrigeration system in motor vehicle applications. This in itself is significant regarding the environmental impacts of CFCs and any potential hazard to the occupants.
3. It must be understood that this work can only be viewed as results from a prototype which will have to be greatly improved with further development. The claim that is made from this work is that it has shown the feasibility of such a system in a positive frame.

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