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ADVANCEMENT IN AUTOMOBILE AIR-CONDITIONING SYSTEM BASED ON JET REFRIGERATION CYCLE

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ABSTRACT

Waste heat operated cooling is comprised of many attractive features in domestic as well as industrial uses and is way towards a sustainable energy system. The performance of such cooling systems is strongly dependent on running conditions of an engine. These cooling systems can be efficiently operated in locations where the sufficient amount of exhausted heat from an engine is available. A waste heat-driven jet refrigeration system has been selected as a case study for a further detailed investigation. In which the exhausted heat from an engine used as a driving agent for the cooling cycle. The low temperature heat source can be used to drive the ejector refrigeration cycle, making the system suitable for integration with the heat exchanger. System performance depends on the choice of working fluid (refrigerant), operating conditions and ejector geometry. The most significant part of the thesis is to analyze the waste heat coming out from a an engine and use of this heat to drive the cooling system of the vehicle to provide comfortable conditions in the interior without using any additional mechanical work as used in current scenario.

KEYWORDS: Engine waste heat recovery, jet air conditioning system, advance car cooling system.

INTRODUCTION

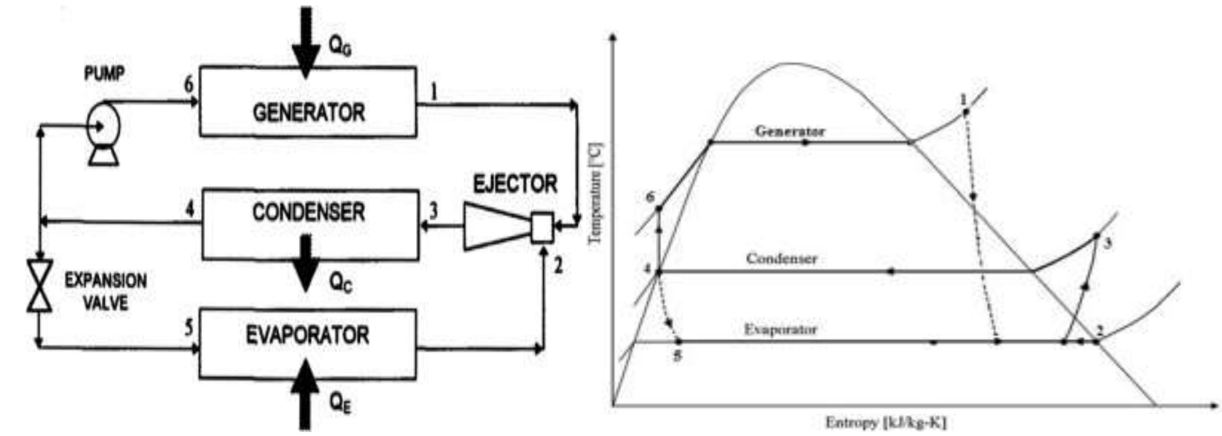
Refrigeration is a process of maintaining low temperature in comparison to surrounding temperature. "Refrigeration is the process of removing heat from an enclosed space, or from a substance, and rejecting it elsewhere for the primary purpose of lowering the temperature of the enclosed space or substance and then maintaining that lower temperature." The vapour absorption refrigeration is heat operated system. It is quite similar to the vapour compression system. In both the cases, there are evaporator and condenser. The process of evaporation and condensation of the refrigerant takes place at two different pressure heads to obtain refrigeration in both the cases. The method employed to form the two different pressure levels in the system for evaporation and condensation of the refrigeration. The circulation of refrigerant in both the cases is also different.[1,2]

IMPORTANCE OF WORK

This invention relates to heat transfer apparatus, and hance, ejector type cooling systems or heat pump systems employing heat as a source of power. Therefore many types of refrigeration or heat pump systems have been provided. Many types are determined by the grade of energy required to power them. For instance, one type, the mechanical compressor cooling systems require mechanical or electrical energy to power it, the mechanical or electrical energy being the highest grade of energy and is reversibly convertible.[3] However, in many instances high grade energy is not economical to use in powering cooling systems. Thus, another type of refrigeration system currently being used is the absorption refrigeration system which can run from heat energy which, however, must be at a fairly high temperature level. Another kind of refrigeration system is the ejector type refrigeration system which is likewise powered from heat energy at a fairly high temperature level. A further object of this invention is to provide a waste heat operated cooling system for an automobile interior with the help of a heat exchanger which transfer the waste heat of exhaust gases of an automobile to the generator of the ejector cooling system. Current work is to provide a thermally powered refrigeration system that is capable of operating from a relatively small temperature difference between the heat source and the ejected heat at the condenser.[4,5]

CALCULATIONS

The schematic diagram and T-s diagram is shown in figure given below:



As we know that the domestic vapour absorption refrigeration systems works between 0.5 to 1.0 kg/min of refrigerant flow rate (from design point of view) .Hence, taking mass flow rate of refrigerant (R-11) in power loop is 0.65 kg/min. (refer previous figure)

Loop 1 (Power)

[a]. Pump work. The liquid refrigerant release from condenser at point 4 and divided into two parts one is in refrigeration section and another is in power section. In power loop this liquid refrigerant gets compressed in refrigeration pump. The liquid refrigerant get pressurized from point 4 to point 6. The work required to acquires such pressure of refrigerant can be calculated as :

Pump work (W_P) = $v_f\,(p_6 - p_4) \times$ mass flow rate.

$= 0.000871(13.18 - 10.16) \times 10^5 \times 0.65$

= 170.97 J/min...(1)

Also, $W_P = m_1(h_6 - h_4)$...............................(2)

From (1) and (2),

$0.65(h_6 - 256.43) = 0.17097$

h_6 = 256.26 kJ/kg

[b]. Heat required for generator. After pressurizing the liquid refrigerant entering to a closed chamber (generator) at point 6. Here the refrigerant get heated by means of exhaust heat and converted into vapour. This vapour refrigerant is exit at point 1 (superheated by 20℃). The value of C_p for the refrigerant is 0.578 kJ/kg K. Hence the amount of heat required for evaporate the liquid refrigerant can be calculated by the expression:

(let the vapour exit from the generator is superheated by 20℃)

$Q_G = m_1(h_1 - h_4)$

$h_1 = h_g + m_1\, C_p\, \Delta T$

$= 430.40 + \{0.65 \times 0.578\,(20)\}$

= 437.5 kJ/kg.

Now,

$Q_G = m_1(h_1 - h_4)$

$= 0.65(437.5 - 256.26)$ kJ/min

= 117.8 kJ/min OR 1.96 kW

Assuming that the effectiveness of heat exchanger (generator) is 90%.

Hence, actual heat required in the generator will be 1.1 times of ideal or calculated value of Q_G. the actual Q_G can be calculated as :

$(Q_G)_{act.} = 1.1 \times 117.8$ kJ/min

$(Q_G)_{act}$ = 129.58kJ/min OR 2.16 kW........(3)

Loop 2 (Refrigeration loop).

(Considering non-isentropic expansion and mass flow rate in the loop is 0.75 kg/min.)

[a]. Heat absorbed in evaporator. The liquid refrigerant enters to the evaporator (point 5) and after absorbing the heat from the surroundings; the liquid refrigerant is converted into vapour state. Along with the assumption that the refrigerant get dry saturated after absorbing its latent heat in evaporator. So, From Figure, the total heat absorbed in the evaporator, Q_E is given by:

$\mathbf{Q_E = m_2 (h_2 - h_5)}$ **kJ/min**

Hence, $h_5 = h_{f4} = 256.43$ kJ/kg

Along with the assumption that the refrigerant 95% dry after absorbing heat in evaporator. So,

$h_2 = h_{f2} + xh_{fg}$

$h_2 = 213.39 + (0.95 \times 197.46)$

$h_2 = 400.9$ kJ/kg

$Q_E = m_2 (h_2 - h_5)$ kJ/min

$= 0.75(400.9 - 256.43)$

$\mathbf{Q_E = 108.41}$ **kJ/min**

Assuming that the effectiveness of heat exchanger (evaporator) is 90%.

Hence, actual heat absorbed in the evaporator will be 0.95 times of ideal or calculated value of Q_E. The actual Q_E can be calculated as :

$(Q_E)_{act.} = 0.95 \times 108.41$ kJ/min

$\mathbf{(Q_E)_{act} = 102.98}$ **kJ/min**............................(4)

[b]. Heat rejected in condenser. Assuming that the refrigerant vapour get superheated by 10 ℃ in mixing chamber. Hence in condenser the refrigerant release its sensible heat and become dry saturated after that its latent heat to the atmosphere and converted in liquid form. After that the liquid refrigerant is exit from the condenser at point 4.

Since the mass flow rate in section 1is 0.65 kg/min whereas in section2 it is 0.75 kg/min. The condenser is the intermediate part for the both sections. Hence condenser should have the capacity to handle the mass flow rate of 1.4 kg/min and convert it into liquid state. The heat rejected in the condenser is calculated as:

$Q_C = m (h_3 - h_4)$ kJ/min

$$h_3 = \frac{m_1 h_2 + m_2 h_1}{m_1 + m_2}$$

$$= \frac{0.65*400.9+0.75*437.5}{0.65+0.75} = 417.40 \text{ kJ/kg.}$$

$Q_C = m (h_3 - h_4)$ kJ/min

$= (0.65 + 0.75)(417.4 - 256.43)$

$\mathbf{Q_C = 225.37}$ **kJ/min**

Assuming that the effectiveness of heat exchanger (condenser) is 90%.

Hence, actual heat rejected in the condenser will be 0.9 times of ideal or calculated value of Q_C. The actual Q_C can be calculated as :

$(Q_C)_{act.} = 0.9 \times 225.37$ kJ/min

$\mathbf{(Q_C)_{act} = 202.8}$ **kJ/min**.............................(5)

EXHAUST HEAT ANALYSIS

The temperature of exhaust gases coming out from the engine is approximate 240℃ where as the surrounding atmosphere temperature is taken as 20 ℃. Mass flow rate of these exhausted gases is 0.04733 kg/s (obtain by applying heat balance equation on engine) and specific heat of these flue gases is taken 1.05 kJ/kg-K. Hence the amount of heat exhausted through silencer can be calculated with the help of expression given below,

Heat exhausted = $m_g c_p \Delta T$

Where,

m_g = mass flow rate of exhaust gas (kg/s)

c_{pg} = specific heat of exhaust gas (kJ/kg-K)

ΔT = temperature difference between exhaust and atmosphere (K)

Hence,

Heat exhausted = 0.04733 * 1.05 * (513 - 293) kJ/s

= 10.93 kJ/s OR 655.8 kJ/min

CONCLUSION

Considering the impact of Global Warming Potential (GWP) waste heat driven vapour absorption system shows a very prospective alternative in refrigeration system. From the Environmental point of view this system is Eco-friendly as it involves the use of R-11 as a refrigerant which is not a chloro-fluoro refrigerant and not responsible for Depletion of ozone layer. Hence we can technically concluded that Out of the total heat supplied to the engine in the form of fossil fuel, approximately, 35 to 45% is converted into useful mechanical energy; the rest heat is expelled to the environment in the form of exhaust gases and cooling systems, resulting in to entropy rise and serious pollution in surrounding, hence this is required to use of this waste heat into useful work. The recovery and utilization of waste heat not only minimize fuel consumption but also reduces the amount of waste heat and greenhouse gases damped to environment. The study resulted possibility of waste heat from internal combustion engine, also describe loss of amount of exhaust energy of an internal combustion engine. Possible methods to recover the waste heat from internal combustion engine and performance and emissions of the engine.

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