Study of Adsorption Refrigeration System in Automobile Air Conditioning Powered by Exhaust Gases

Onkar Dhadge[1] Prateek Kulkarni[2] Indrajeet Hulyalkar[3] Shubham Kudke[4] Chandan.M.N[5]
[1,2,3,4]BE Student [5]Assistant Professor
[1,2,3,4,5]Department of Mechanical Engineering
[1,2,3,4,5]Trinity Academy of Engineering, Maharashtra, India

Abstract— 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 radiator and one third is wasted as heat at the exhaust system, even for relatively small car engine. Heat energy can be utilized from the exhaust gas this heat energy is enough to power an adsorption air conditioning system to produce the air conditioning effect. It is a well-known fact that a large amount of heat energy associated with the exhaust gases from an engine is wasted. Heat energy can be utilized from the exhaust gas this heat energy is enough to power an adsorption air conditioning system to produce the air conditioning effect.
Key words: Adsorption, Exhaust, Heat Exchanger, Absorption, Coolant

I. INTRODUCTION

This paper relates to use of adsorption refrigeration system as an alternative to conventional vapor compression cycle used in automobiles nowadays. Adsorption is the adhesion of atoms, ions or molecules from a gas, liquid or dissolved solid to a surface. This process creates a film of the adsorbate on the surface of the adsorbent. This process differs from absorption, in which a fluid is dissolved by or permeates a liquid or solid respectively.

Adsorption refrigeration is similar to absorption refrigeration. The difference is that in adsorption refrigeration the working fluid molecules adsorb onto the surface of a solid instead of dissolving into a fluid. The step in which heat is added results in working fluid molecules desorbing from the solid.

Adsorption (also called "solid sorption") refrigeration systems use solid sorption material such as silica gel and zeolite to produce cooling effect. These systems are attracting increasing attention because they can be activated by low-grade thermal energy and use refrigerants having zero ozone depletion potential and low global warming potential. The adsorption refrigeration system has several advantages compared to the absorption refrigeration system.

II. LITERATURE REVIEW

An overview on adsorption cooling systems powered by waste heat from IC engine, Ahmed" Askalany, Nader.S.Koura, KhaledHarby, Elsevier publication, 10th July 2015. The paper presents an extensive review of the state of the art of adsorption cooling systems used in automobiles air conditioning. Chlorofluorocarbon and hydro chlorofluorocarbon refrigerant have been widely used in traditional cooling system. These refrigerants accelerate the depletion of earth's ozone layer. Therefore adsorption air conditioning technology attracted much attention as it powered by waste heat can help to reduce required energy and thermal pollution. [1].

Adsorption refrigeration system for cabin cooling of trucks, Harish Tiwari, Dr.G V Parishwad, IJETAE publication, 10th October 2012.Literature review in alternative cooling systems with activated carbon and NH3 as adsorbent refrigerant pair is selected and used. The exhaust of an IC engine test rig is used to supply the necessary heat to the adsorbed. The setup consists of two absorbers, two condensers, and one evaporator the condensers are connected to the evaporator through control valve. Two absorber beds are proposed, one in heating mode and another in cooling mode. One of the absorber is charged with refrigerant ammonia. [2].

Performance analysis of an adsorption refrigerator using activated carbon in a compound adsorbent, Z.S Lu, R.Z Wang, L.W Wang, C.J Chen, 13th September 2005, Elsevier publication The work has adopted two new concepts, mixture of activated carbon and CaCl2 as adsorbent and heat pipe for heat transfer which are really very effective to improve the performance of adsorption refrigeration systems .In comparison with activated carbon and CaCl2, has a high volume adsorption capacity while avoiding the problems of agglomeration and performance attenuation the high adsorption performance system from presence of activated carbon with its important network of pore cavities which contribute to enhance significantly the mass transfer. [3].

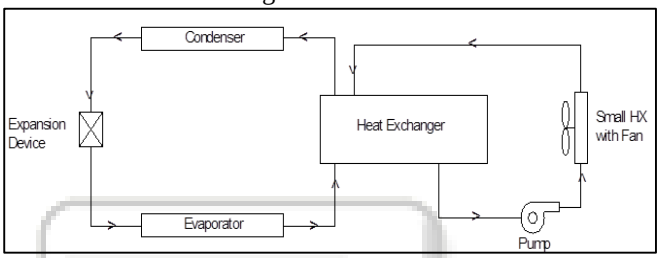
Analysis for composite zeolite/foam aluminum - water mass recovery adsorption refrigeration system driven by engine exhaust gas, Penghu, Juan-Juan Yao, Ze-Shao Chen ,20th September 2008,.Elsevier publication. The driving scenarios of engine working conditions can affect the performance of adsorption refrigeration greatly. Therefore, an adsorption refrigeration system is more suitable for automobile that are usually driven on the highway, such as long distance coach or truck. Automobile air conditioning currently is performed by vapor compression refrigeration system but the refrigerants in vapor compression refrigeration systems are mainly HCFC's and HFC's which are not environmental friendly refrigerants and can be driven by waste heat from automobile's engine.[4]

By studying various papers it shows that the exhaust gases contain large amount of heat energy which can be utilize to power the adsorption refrigeration system.

III. PRINCIPLE OF OPERATION

The basic diagram is similar to the vapour compression refrigeration system but in vapour adsorption refrigeration system the compressor is replaced by two different heat exchangers. These heat exchangers are called as adorbers. These adsorbers are the most important parts of the system.The remaining cycle is similar to VCR cycle followed by condenser, expansion device and then evaporator. The whole system is divided into two different cycles . The first

cycle is as explained as follows: The hot gases from exhaust of vehicle are passed to the heat exchanger. The refrigerant from the evaporator are passed through the heat exchanger, here the temperature of this refrigerant is raised high. This refrigerant is then passed to the condenser where its temperature and pressure is lowered to a certain extent. This refrigerant coming out from condenser is then passed through expansion device where there is a sudden drop in temperature of the refrigerant. This refrigerant again goes to the evaporator section and the cycle continues. The second cycle is explained as follows: The refrigerant from cycle one gets in contact with other refrigerant of water and glycol in heat exchanger where it loses its heat up to certain temperature. This refrigerant of water +glycol is passed through the small heat exchanger. This secondary heat exchanger is mounted with fan. These fans helps for higher rate of heat exchange and results in better cooling of refrigerant of water +glycol. A small coolant/water pump is used to pump the refrigerant between the heat exchangers.



IV. COMPONENTS

A. Primary Heat Exchanger:

The heat exchanger is a three fluid system with 1 fluid as hot exhaust gases coming out from the vehicle, 2nd fluid as coolant mixture of water and glycol in different proportions and 3rd fluid as refrigerant R134 a. The central pipe is assigned to hot flue gases. This pipe is of 30mm diameter, where the intake of this type is will be attached to exhaust flue gasses coming out from the vehicle. The 1st pipe is assigned for coolants which are further extended in to 6 pipes. This is 19mm diameter, where the water and glycol coolant flow through the pipe. From this coolant pipe the heat is rejected to the activated carbon and heat of hot flue gages is carried out. It maintains the temperature of the whole system and keeps the heat exchanger at stabilization from getting overheated.

B. Secondary Heat Exchanger

A heat exchanger is a device used to transfer heat between a solid object and a fluid, or between two or more fluids. The fluids may be separated by a solid wall to prevent mixing or they may be in direct contact. They are widely used in space heating, refrigeration, air-conditioning, power stations. The classic example of a heat exchanger is found in an internal combustion engine in which a circulating fluid known as engine coolant flows through radiator coils and air flows past the coils, which cools the coolant and heats the incoming air. Another example is the heat sink, which is a passive heat exchanger that transfers the heat generated by an electronic or a mechanical device to a fluid medium, often air or a liquid coolant.

C. Axial Fan:

The axial design uses axial forces to achieve the movement of the air or gas, spinning a central hub with blades extending radially from its outer diameter. The fluid is moved parallel to the fan wheel's shaft, or axis of rotation. The axial fan wheel is often contained within a short section of cylindrical ductwork, to which inlet and outlet ducting can be connected. In general, axial fans are used where the principal requirement is for a large volume of flow, and the centrifugal design where both flow and higher pressures are required.

D. Coolant Pump

This pump will be used to circulate the water glycol coolant throughout the heat exchanger and to maintain its temperature. Voltage: 12V DC Current: 3ampDischarge: 8-10LPM operating temperature: 120º C

E. Coolant (Water and Glycol)

Ethylene glycol is a colorless, practically odorless, low-volatility, low-viscosity, hygroscopic liquid. It is completely miscible with water and many organic liquids. The hydroxyl groups on glycols undergo the usual alcohol chemistry, giving a wide variety of possible derivatives. Hydroxyls can be converted to aldehydes, alkyl halides, amines, azides, carboxylic acids, ethers, nitrate esters, nitriles, nitrite esters, organic esters, peroxides, phosphate esters and sulfate esters. This chemistry permits ethylene glycol to act as an intermediate in a wide range of reactions. Especially significant is resin formation, including the condensation with dimethyl terephthalate or terephthalic acid resulting in a polyester resin. Ethylene Glycol based water solutions are common in heat-transfer applications where the temperature in the heat transfer fluid can be below 32ºF (0ºC). Ethylene glycol is also commonly used in heating applications that temporarily may not be operated (cold) in surroundings with freezing conditions - such as cars and machines with water cooled engines.

F. Refrigerant (R-134a)

R134a is also known as Tetrafluoroethane (CF3CH2F) from the family of HFC refrigerant. With the discovery of the damaging effect of CFCs and HCFCs refrigerants to the ozone layer, the HFC family of refrigerant has been widely used as their replacement. It is now being used as a replacement for R-12 CFC refrigerant in the area of centrifugal, rotary screw, scroll and reciprocating compressors. It is safe for normal handling as it is non-toxic, non-flammable and non-corrosive.

V. SUMMARY

This paper presented will give an introduction on an advanced way of utilizing the waste exhaust gases and thus reducing the emissions. This would also help in improving the fuel efficiency of the vehicle. This adsorption system could prove breakthrough in automotive industry.

VI. FUTURE SCOPE

Any change can be done that can bring an overall improvement in the system COP or material saving or more simple design procedure. Any other parameters effect can be

studied. Of course the future scope also lies in the system fabrication and practical application. More efficient cooling can be done using different type of coolant for better cooling effect. This can improve effectiveness of the heat exchanger.

It can also be used as two fluid systems or three fluid system depending upon how much cooling is to be achieved. It can be used in vehicle air conditioning system for better cooling effect and better efficiency. This heat exchanger can be used in different industries. A heat recovery system can be built into a new plant or retrofitted to an existing plant. This system can be implemented in automobile industry also. As this system replaces the compressor with absorbers, the power consume by compressor is taken by engine could be save. And this improves efficiency of engine subsequently increases fuel efficiency. Using different type of refrigerant can improve the cooling and various experimentations can be done. Modifications can be made in the heat exchanger as per the requirement of the system.

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