Improved Performance of VARS using Minichannel Condenser

Sagar Wankhede [1], Shubham Shinde[2], Sumit Nagothkar[3], Dhananjay Hingmire[4], Atul Yadav[5]

[1, 2, 3, 4, 5]Department of Mechanical Engineering
[1, 2, 3, 4, 5] Sinhgad Institute of Technology, Lonavala

Abstract- *A considerable part of the energy generated by an automotive internal combustion engine and in the boiler power plant is wasted as heat in the exhaust system. This wasted heat could be recovered and can applied to the vapour absorption systems. The exhaust system of the specific source is to be connected to the generator element of an absorption refrigeration system. This paper presents an analytical study of a Li-Br –water absorption refrigeration system using the exhaust heat energy source. This paper is concerned with numerical modeling of mini-channel condenser for Vapour Absorption Refrigeration System. . A prototype of a CAD model of absorption system for refrigeration using heat from the exhaust-gases is to be designed and work in process for the test in CFD software. The design calculations are carried out for the capacity of 1 TR. In the present work, the simple condenser has been replaced by Mini channel condenser. The replacement of the simple condenser by mini-channel condenser will reduce the size of the condenser.*

Key words: Mini-channel condenser, vapour absorption system.

I. INTRODUCTION

The needs for thermal comfort in housing and office buildings generate a strong increase in energy demand especially during summertime. Air conditioning systems are basically mechanical vapor compression types, which use high grade electrical energy generated in power stations using fossil fuels. Due to this situation by using the non-renewable energy source we can decrease the consumptions of the renewable energy source. Basically Air-Conditioning is done by the vapour compression refrigeration system due to its high coefficient of performance and compactness but there are some serious drawbacks of this system like the vapour compression refrigeration system normally used chlorofluorocarbon (CFC) and hydroflurocarbon (HCFC) as refrigerants which are anti-environment This refrigerant causes global warming and radiation-inflicted diseases when react with ozone.

On a preliminary evaluation of the vapour-absorption refrigeration system (VARS), it is found that it can be used as an alternative refrigeration system. The vapour absorbtion system is mainly runs on the waste heat such that extra steam from boiler or exhaust gases from IC engine due to these input heat source the running cost of the system is much lesser than vapour compression system. The absorption refrigeration system differs fundamentally from vapor compression system only in the method of compressing the refrigerant. An absorber, generator and pump in the absorption refrigerating system replace the compressor of a vapor compression system.

II. LITERATURE REVIEW

Manzela[1] have worked on assessment of an experimental study of an ammonia–water absorption refrigeration system using the exhaust of an internal combustion engine as energy source. The exhaust gas energy availability and the impact of the absorption refrigeration system on engine performance, exhaust emissions, and power economy are evaluated. The engine was tested for 25%, 50%, 75% and wide-open throttle valve. The refrigerator reached a steady state temperature between 4 and 13 °C about 3 h after system start up, depending on engine throttle valve opening Exhaust hydrocarbon emissions were higher when the refrigeration system was installed in the engine exhaust, but carbon monoxide emissions were reduced, while carbon dioxide concentration remained practically unaltered. This work has as an objective the study of the feasibility and potential of using the internal combustion engine exhaust gas as energy source for an absorption refrigeration system. For this purpose was performed an experimental study on a commercial 215-l refrigerator. The impact of the absorption refrigeration system on engine power output and exhaust emissions is analyzed, in order to know how this system influences the operation of an internal combustion engine.

Gebreslassie[2] have worked on assessment of optimization of sustainable single-effect water/Lithium Bromide (LiBr) absorption cooling cycles. The multi-objective formulation accounts for minimization of the chiller area as well as the environmental impact associated with the operation of the absorption cycle. A set of design alternatives were provided for the absorption cycles rather than a single design; the best design can be chosen from this set based on the major constraints and benefits in a given application. The proposed approach were illustrated design of a typical absorption cooling cycle. Absorption cycles were gaining popularity in air conditioning systems because of benefits to both the environment and energy consumption. The main advantage of heat-driven chillers compared to vapor compression cooling cycles were their capability to utilize the low-grade energy available from fossil fuel power plant discharge, solar, geothermal, and biomass energy sources as well as from waste heat recovered from thermal systems. Moreover, working fluids in absorption systems did not contribute to ozone layer depletion and have zero global warming potential.

Li, et al[3] has done work on transport air conditioning (AC) systems which were very important energy to provide comfort for passenger compartment in metro car or railway car. The determination of cooling load and understanding of their variations are critical for the efficient design of the transport air conditioning system. In this paper, the variation of cooling load in a compartment of metro car or railway car is numerically investigated. Ambient condition, inside condition, car speed, fresh air volume, solar time and number of passengers were taken into consideration as key factors for the numerical simulation and analysis. The investigation was first performed on a compartment without air conditioning unit. Then the entire system which included air conditioning unit and the compartment were studied.

Rego, et al[4] have worked on assessment of an automotive internal combustion engine was wasted as heat in the exhaust system. This wasted heat could be recovered and applied to power auxiliary systems in a vehicle, contributing to its overall energy efficiency. The experimental analysis of an absorption refrigeration system was performed. The exhaust system of an automotive internal combustion engine was connected to the generator element of an absorption refrigeration system. The performance of the absorption refrigerator was evaluated as a function of the supplied heat. The use of a control strategy for the engine exhaust gas mass flow rate was implemented to optimize the system. Exhaust gas flow was controlled by step-motor actuated valves commanded by a microcontroller in which a proportional-integral control scheme was implemented. Information such as engine torque, speed, key temperatures in the absorption cycle, as well as internal temperatures of the refrigerator was measured in a transient regime. The results indicated that the refrigeration system exhibited better performance when the amount of input heat was controlled based on the temperature of the absorption cycle generator. It was possible to conclude that, by dynamically controlling the amount of input heat, the utilization range of the absorption refrigeration system powered by exhaust gas heat could be expanded in order to incorporate high engine speed operating conditions.

Lu, et al,[5] have worked on assessment of the recoverable waste heat from the coolant and exhaust system has been analyzed under engine overall operational region. Based on these results, the working conditions of a cogeneration are designed and the performance of the cogeneration is evaluated throughout the engine operating region

Ketfia, et al[6] have worked on assessment of refrigeration based on vapour compression principle uses high grade electrical energy, and refrigerant fluid with a global worming and ozone depletion potentials. Absorption machines using solar thermal energy were excellent alternatives to mechanical refrigeration. Absorption cooling systems were mature technologies that proved their abilities to provide clean cooling with the use of low grade solar and waste heat.

Qi, et al[7] have worked on assessment of retrofitted compact and high efficient micro channel heat exchangers were proposed. The new mini-channel heat exchangers have advantages in compactness (17.2% and 15.1% volume reduction for evaporator and condenser, respectively), weight (2.8% and 14.9% lighter for evaporator and condenser, respectively), heat transfer characteristics compared with the currently used heat exchangers in mobile air conditioning (MAC) industry.

Ali, et al[8] have worked on assessment of waste heat from engine can be utilized to drive an absorption cooling system for air conditioning purposes in the vehicle cabin, which not only improves the fuel economy but also reduces the carbon footprint. It was also important to reduce the size of the adsorption bed to adopt the adsorption technology for air-conditioning applications in passenger cars, buses and trucks or even trains.

VAPOUR ABSORPTION REFRIGERATION SYSTEM

The absorption cycle is similar in certain respects to the vapour compression cycle. A refrigeration cycle will operate with the condenser, expansion valve, and evaporator shown in Figure 1. If the low-pressure vapour from the evaporator can be transformed into high pressure vapour and delivered to the condenser. The absorption system first absorbs the low-pressure vapour in an appropriate absorbing liquid. Embodiment in the absorption process is the conversion of vapour into liquid; since the process is a kin to condensation, heat must be rejected during the process. The next step is to increase the pressure of the liquid with a pump, and the final step releases the vapour from the absorbing liquid by adding heat.

The vapour-compression cycle is described as a work-operated cycle because the increase of pressure of the refrigerant is accomplished by a compressor that requires work. The absorption cycle, on the other hand, is referred to as a heat operated cycle because most of operating cost is associated with providing the heat that drives off the vapour from the high-pressure liquid. Indeed there is a requirement for some work in the absorption cycle to drive the pump, but the amount of work for a given quantity of refrigeration is minor compared with that needed in the vapour compression cycle.

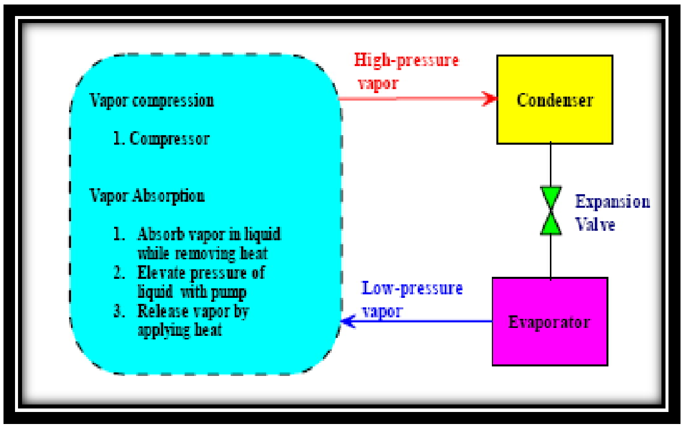

Figure 1:-Methods of transforming low-pressure vapour into high pressure

Many working fluids are suggested in literature. There are some 40 refrigerant compounds and 200 absorbent compounds available. However, the most common working fluids are water/NH3 and LiBr/Water. Both NH3 (refrigerant) and water (absorbent) are highly stable for a wide range of operating temperature and pressure. Since NH3 and water are volatile, the cycle requires a rectifier to strip away water that normally evaporates with NH3 without a rectifier; the water would accumulate in the evaporator and offset the system performance. The other disadvantages are high pressure, toxicity and corrosive action to copper and copper alloy. However, water/NH3 is low-cost.

The use of LiBr/Water for absorption refrigeration systems began around 1930. Two outstanding features of LiBr/water are non-volatile as an absorbent of LiBr (The need of rectifier is eliminated) and extremely high heat of vaporization of as a refrigerant of water.

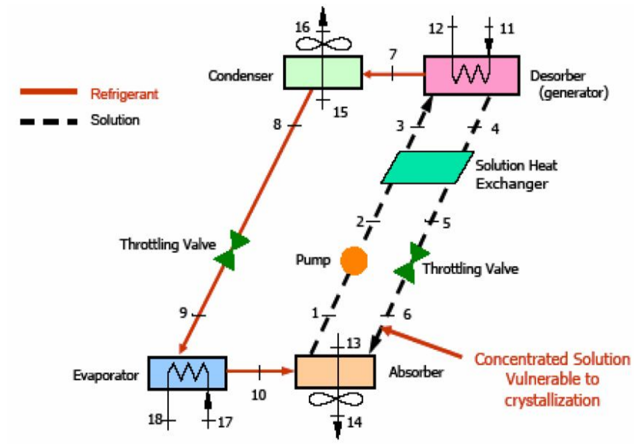

Figure 2:-shows a single effect system using non-volatile absorbent such as LiBr/water.

The main components of an absorption system include the absorber, generator, condenser, evaporator, and solution heat exchanger. In Figure 2, the dashed lines stand for the solution loop and solid lines for the refrigerant loop. Firstly, the LiBr-H2O solution in the absorber, at point (1), gets pumped through the solution heat exchanger (2) into the generator (3). Heat input (11) to the generator allows the water to boil off from the solution into vapor (7). For the refrigerant loop, the water vapor is condensed in the condenser by ambient air (15). The water (8) then passes an expansion valve and continues to the evaporator (9) where it evaporates and provides the desirable cooling effect. The water vapor (10) then gets reabsorbed into the solution in the absorber with the help of the external coolant – ambient air (13) again. For the solution loop, the remaining solution in the generator (4) passes through the solution heat exchanger (5) before re-entering the absorber (6).The heat exchanger allows the solution from the absorber to be preheated before entering the generator by using the heat from the hot solution leaving the generator. Therefore, COP is improved as the heat input at the generator is reduced. Experimental studies show that COP can be increased up to 60% when a solution heat exchanger is used.

III. EXPERIMENTATION

[1] Calculation of Exhaust Heat

The exhaust of each vehicle may vary accordingly, to find out the total exhaust heat we have to do a case study on that vehicle in which we are going to implement this system. It +will give better results when engine is a multi cylinder, as a simple logic behind this, as number of cylinders increases the indicated power increases thus resulting more heat at exhaust.

[2] Calculation of Cooling Load

ASHRAE Handbook of Fundamentals provides two major thermal load calculation methodologies: Heat Balance Method (HBM) and Weighting Factor Method (WFM). HBM is the most scientifically rigorous available method and can consider more details with less simplifying assumptions. Advantages of HBM are that several fundamental model scan be incorporated in the thermal calculations. Although HBM is more accurate than WFM, it is easier to implement WFM for load calculation in a passenger vehicle .However, when more detailed information of the vehicle body and thermal loads is available; HBM is the preferred choice.

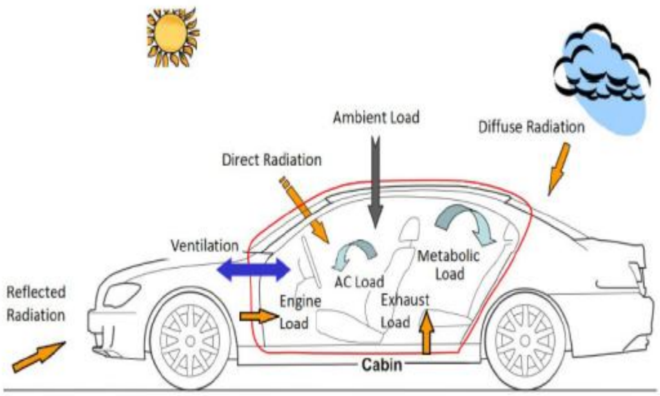

Figure 3:-Various Loads Acting on Vehicle

[3] Engineering Design

The cycle of operation may be static as shown in figure from the evaporator. The refrigerant (water) is evaporated while it is taking heat from the fluid being cooled (air for instance). The water vapour (state 10) is then sucked up by lithium bromide spray injected into the absorber, thus the name absorption system. Due to the exothermic reaction taking place in the absorption process, heat has to be removed, and the mixture of lithium bromide and refrigerant vapour at this stage is called the strong solution (state 1). Strong and weak solution refer to the amount of refrigerant present. The strong solution is then pumped (state 2) through a liquid heat exchanger (state 3) to the generator. This heat exchanger will improve the cycle performance, as will be shown later. In the generator (sometimes called the concentrator) the strong solution is heated and boiled by an external heat source to release the refrigerant vapour (state 7), leaving behind a concentrated LiBr water solution (state 4). The latter is called weak solution since it contains a smaller amount of refrigerant. The refrigerant vapour leaving the generator is condensed (state 8) in the condenser and is directed to the evaporator through an expansion valve (state 9). The weak solution flows back to the absorber through the liquid-liquid heat exchanger as a spray (state 6) to complete the cycle.

IV. THERMODYNAMIC MODELING

The determination of the thermodynamic properties of each state in a cycle, the amount of heat transfer in each component and the mass flow rates at different lines depend on the following input parameters:

Generator Temperature, T_g
Evaporator Temperature, T_e
Condenser Temperature, T_c
Absorber Temperature, T_a
Liquid-Liquid heat exchanger effectiveness, E
Refrigeration Load, Q_L

A. GENERATOR

The Generator operates under high pressure which is controlled either by the temperature of the incoming heat to the Generator or the condensation temperature required by the cooling water entering the condenser. The absorption process generates vapour and extracts the refrigerant from the working fluid by the addition of the external heat from the heat source; it is desorption of water out of a lithium bromide-water solution. The refrigerant vapour travels to the condenser while the liquid absorbent is gravitationally settled at the bottom of the generator; the pressure difference between the generator and the absorber then causes it to flow out to the absorber through an expansion valve Energy Balance on the solution side and heat source

$$Q_{GEN}=m_2h_2+m_8h_8-m_7h_7$$

B. CONDENSER

Brazed aluminium mini-channel condensers are substantially lighter and thinner than mechanical copper condensers. Weight and thickness can be reduced up to 50%, even keeping the same performances. By using the same material for all the components and by brazing them we obtain a flawless and corrosions resistant condenser. The exchanger is completely made in aluminium and can be recycled without any extra costs. A liquid state of a refrigerant is a must in order for the refrigeration process to run. Hence, the vapour phase of a refrigerant from the generator is altered to a liquid by the condenser. The condensing process of a high pressure refrigerant vapour is done by rejecting the vapor’s latent heat to the atmosphere, following a regular heat balance formulation

Energy Balance on the solution side and cooling air are

$$Q_{COND}= m_2h_2- m_3h_3$$

Number channel required in the coolant side is given by

$$Q=UA_CN_C\mathit{LMTD}$$

U-Overall Heat Transfer Coefficient
A_C-Area of Condenser
N_C-Number of Channels
$N_C = W/A + B$
W=Width of the condenser
A= Thickness of the fins
B=Width of the Channel

V. CONCLUSION

Following points can be concluded from the study-

[1] Without hampering the engine performance, the Li-Br and water based vapour absorption system can provide an efficient air conditioning effect in a vehicle cabinet.
[2] VAS is more beneficial than VCRS since VAS use waste heat of exhaust gases which would otherwise get waste to operate, which in turn decrease the fuel consumption and exhaust gas production. While VCRS imposes an extra 10% power load on engine and in turn increases the fuel consumption and exhaust gas production and affect the environment.
[3] Use of minichannel technology will reduce the size of current system as compare to conventional vapor absorption system.

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