Automobile Air-Conditioning Using Mini-Channel Technology in Evaporator-A Review

Hase Y.B.[1], Dhat S.S.[2],Chavan R.K.[3],Dongre S.D.[4],Pesode P.A.[5]
[1, 2, 3, 4, 5] Department of Mechanical Engineering
[1, 2, 3, 4, 5]Sinhgad Institute of Technology, Kusgaon (Bk), Lonavala

Abstract-*With the growing concerns about energy crisis, more attention was drawn to improve the efficiency of the existing energy systems to reduce the energy consumption. A heat balance of an I.C engine shows that only 35-40% of heat energy in the fuel is converted to work, rest 60-65% is taken by lubricants, coolant and the exhaust gases. Exhaust gases contains around 30% of heat energy. Thus, recovering the wasted heat from the IC engine and using it to cool the passenger space by incorporating vapour absorption system can effectively increase the overall energy efficiency, decrease the fuel consumption and reduce the emissions and increase comfort. This paper aims at designing of a prototype of Li-Br and water based vapour absorption refrigeration system using waste heat from the exhaust-gases and its CFD software analysis and developing a numerical model of minichannel evaporator for Vapor Absorption System. Because the absorption refrigeration system uses the Lithium bromide & water solution as refrigerant, it is profitable for the environment, since the values of ODP and GWP of the refrigerant are almost zero. In the commercial vapor absorption refrigeration system a heating coil generator system was employed to vaporize the Li-Br refrigerant. But in this paper, the heat of the exhaust gases from the IC engine has been utilized to vaporize water as refrigerant and the simple evaporator has been replaced by Mini channel evaporator to make the system more compact and efficient.*

Keywords:-Minichannnel Technology, ODP, GWP, IC Engine

I. INTRODUCTION

In the last few decades there has been substantial rise in the number of transportation vehicles due to the population rise. This increase has subsequently caused the huge burden on natural resources[4]. The emission from these motor vehicles has gives rise to green house effect, which is great threat to our environment and survival of mankind. So energy saving and optimizing the existing system is the main priority. A brief analysis of heat balance of IC engine indicates that input fuel energy is divided into three parts, energy that is converted to useful work, energy that loses through the exhaust gas and energy that dissipates to the coolant. A typical I.C engine has thermal efficiency of around 35% [2]. This means rest 65% [2] of energy is taken up by exhaust gases and coolant out of which exhaust gases alone consists of 35% [2] of the total energy. This heat energy is completely wasted. The waste heat from exhaust gases can be utilized to power the air conditioning system of the automobiles. The conventional automotive air conditioners (AC) of vehicles use vapour compression refrigeration system which made use of the engine shaft power to run the mechanical compressor, which imposes an extra 10% power load on engine and in turn increases the fuel consumption and exhaust gas production and moreover the refrigerants used in VCRS system are mainly HCFCs and HFCs [3] which are not environmentally friendly. Thus the growing number of cars with AC-systems are consumed more fuels which not only contribute to serious energy crisis but also cause ecological problems by emitting CO2, SOX, NOX, lead etc [1] ,with the exhaust gas of engine. Some other drawbacks of VCRS are moving parts in the compressor leads to wear, tear and noise, the COP decreases considerably with decrease in evaporator pressure, performance is adversely affected at partial loads[5] , Liquid traces in suction line may damage the compressor, Automatic operation for controlling the capacity is difficult . These shortcomings are eliminated in vapour absorption refrigeration system which uses heat energy rather than mechanical energy. The specific fuel consumption of the vehicle can be minimized if the exhaust gases could be utilized for the production of cooling energy. Thermally driven cooling devices such as vapour absorption cooling system employ waste heat to produce cooling effects at the evaporator. Moving parts are only in the pump, which is a small element of the system. Hence operation is smooth. The system can work on lower evaporator pressures also without affecting the COP. There is no effect of reducing the load on performance. Liquid traces in evaporator do not affect the working and automatic operation for controlling the capacity is easy[9].

Evaporators of small and medium refrigeration systems, as in commercial and mobile air conditioning applications, are being studied to develop more compacts and lighter equipments that reach a good thermal performance and reliability, with low pressure drop. In this way, the evaporators are being designed with small tubes or channels and light materials, like aluminum. Due to the increase in use of this compact two phase heat exchangers, the investigation of flow boiling heat transfer and pressure drop in small channels became more important in recent years[15]. The mini-channel heat exchangers are more compact and have higher heat transfer rate in comparison to the conventional compact heat exchangers such as plate type heat exchangers for the same external geometry. Since mini-channel heat exchangers have much less internal volume than the conventional compact heat exchangers, the system using mini channel evaporators requires less refrigerant charge.

Figure 1 shows the schematic diagram of mini-channel evaporator which is composed of louver fins and minichannel flat tubes. There are two rows of parallel flow mini-channel tubes with inlet and outlet headers in this design. The refrigerant flowing to the flat tube is divided to mini-channel tubes.

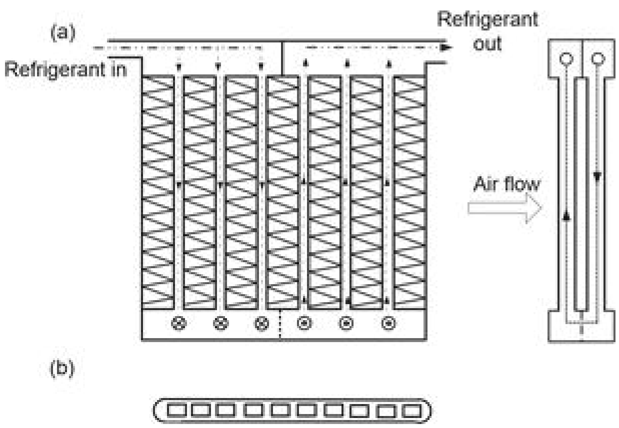

Fig. 1**.**The schematic view of a parallel flow evaporator. (a) Front view of parallel flow evaporator. (b) mini-channel cross-sections

Following are the advantages of mini-channel evaporator over laminated evaporator which is used conventionally[8].

- The mini-channel heat transfer rate was higher than that of the laminated evaporator in all operating conditions.
- The air exit temperature for mini-channel evaporator was lower than that for laminated one which causes to reduce the inside cabin air temperature to a comfortable degree faster when the first evaporator type were used.
- This provides shorter operating time and lower power consumption of compressor when mini-channel evaporator was used as well as lowers vehicle fuel consumption.
- The mini-channel evaporators have further advantages of 33% more compactness and 20% [8] lighter weight than that of laminated evaporator.
- The mini channel evaporator had higher cooling capacity (7.2%) and higher refrigerant pressure drop (45%) [8] incomparison with the corresponding values in laminated evaporator assuming the same external geometry.
- The outlet air temperature and enthalpy of minichannel evaporator was also lower, 11% and 8% [8]respectively, than that for laminated evaporator. This cause to reduce the time period as well as power/fuel consumption for reaching the comfortable cabin temperature.

II. LITERATURE REVIEW

Ali, Chakraborty et al. [1] Waste heat from engine can be utilized to drive an adsorption cooling system for air conditioning purposes in the vehicle cabin, which not only improves the fuel economy but also reduces the carbon footprint. It is 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.

Alqdah, et al. [2]In his investigation; analysis and design of an automobile air conditioner was made by utilizing the available diesel engine exhaust waste energy to provide the required heat for the generator. Because automotive air conditioning is one of the most equipment that heavily uses CFC compounds, and the leakage of CFCs from such air conditioners affect the environment, the absorption cycle was found to be an ideal option. Cooling load for the automobile has been estimated and found to be within acceptable ranges which are about 1.37 TR. The reported results show that the COP values directly proportional with increasing generator and evaporator temperatures. Measured COP values of the proposed model varied between 0.85 and 1.04.

Eckhard .et al [3]A rigorous mathematical approach is developed for 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 are 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 is illustrated design of a typical absorption cooling cycle.

Ketfia , et al. [4] Mechanical refrigeration based on vapor compression principle uses high grade electrical energy, and refrigerant fluid with a global worming and ozone depletion potentials. Absorption machines using solar thermal energy are excellent alternatives to mechanical refrigeration. Absorption cooling systems are mature technologies that proved their abilities to provide clean cooling with the use of low grade solar and waste heat.

Kumar, et al. [5] His paper aims at reviewing the automobile air conditioning by vapour absorption system utilizing heat of exhaust gases. In recent years the scientific and public awareness about the conservation of natural resources has focused our attention for developing energy efficient system from energy and exergy consideration. A lot of research is aimed to optimize the I.C engine which takes up about 35-40% [8] of total oil consumption. Exhaust gases contains around 30% of heat energy[8]. This heat in exhaust gases can be tapped to cool the passenger space by incorporating vapour absorption system. So use of VARS seems very promising and attractive alternative.

Mathapati, et al. [6] Energy from an exhaust of an internal combustion engine is used to power an absorption refrigeration system to air condition an ordinary passenger vehicle. Feasibility study has been done to find out the energy available from exhaust gas of a vehicle. Cooling load for the automobile has been estimated. In this paper theoretical evaluation of LiBr-Water based absorption refrigeration system is presented.

Manzela, et al. [7] His work presents 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.

Rego, et al. [8]A considerable part of the energy generated by an automotive internal combustion engine is 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. In the his work, 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 is 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. The results indicated that the refrigeration system exhibited better performance when the amount of input heat is controlled based on the temperature of the absorption cycle generator.

Wenhua, et al. [9] Transport air conditioning (AC) systems are the 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 are taken into consideration as key factors for the numerical simulation and analysis. The investigation is first performed on a compartment without air conditioning unit. Then the entire system which includes air conditioning unit and the compartment are studied.

Yaodong, et al. [10]The recoverable waste heat from the coolant and exhaust system has been analysed 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.

Zhaogangi, et al. [11]In the present paper, two retrofitted compact and high efficient microchannel heat exchangers were proposed. The new microchannel 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.

Yin et al. [12] developed a CO2 mini-channel gas cooler model. In their model, each pass was separated into 10 equal length element. The model predicted the gas cooler capacity with a good accuracy.

Asinari et al. [13] developed a mini-channel gas cooler model based on predicting the hot and cold sides flow convection heat transfer coefficients. They reported that the accuracy of modeling results of evaporator cooling capacity prediction could be improved if thermal conduction inside metal was included in the gas cooler model.

Shao et al. [14] developed a numerical model for serpentine mini-channel condenser. The results of their modeling showed a good match with experimental results. The number of literature on thermal modeling of mini-channel evaporators is not too many.

Kim & Bullard [15] developed a model for CO2 microchannel evaporator. The model was based on using the finite volume analysis of air-side heat and mass transfer processes. They neglected the tube wall thermal resistance in the proposed model.

Qi et al. [16] experimentally studied the mini-channel evaporators in a refrigeration system test bench and compared the results of two mini-channel and conventional laminated evaporators (compact heat exchangers with hydraulic diameter bigger than 3 mm) in mobile air conditioning system.

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 2 shows various loads acting on vehicle.

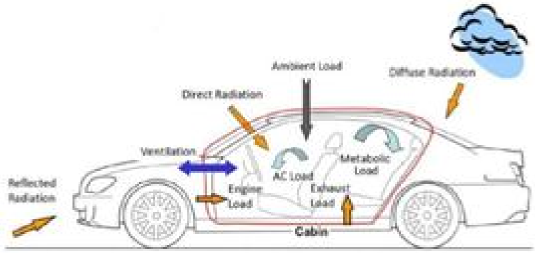

Fig 2-Various load acting on vehicle. [11]

[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-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.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 mini-channel technology will reduce the size of current system as compare to conventional vapor absorption system.

REFERENCES

[1] S.M. Ali , A. Chakraborty, “Using engine exhaust gas as energy for an absorption refrigeration system” Applied Energy,2011,vol.83, pp. 1141–1148.

[2] Alqdah K., Alsaqoor S., Al-JarrahA.,“Design and Fabrication of Auto Air Conditioner Generator Utilizing

Exhaust Waste Energy from a Diesel Engine” Int. J. of Thermal & Environmental Engineering,vol.46 ,pp. 100-110.

[3] Eckhard B.G., Groll A., Garimella S.V., “Multi-objective optimization of sustainable singleeffect water/lithium bromide absorption cycle” Renewable Energy,2012,vol.46pp. 100110.

[4] S.M. Ali , A. Chakraborty, “Using engine exhaust gas as energy for an absorption refrigeration system” Applied Energy,2011,vol.83, pp. 1141–1148.

[5] Alqdah K., Alsaqoor S., Al-JarrahA.,“Design and Fabrication of Auto Air Conditioner Generator Utilizing Exhaust Waste Energy from a Diesel Engine” Int. J. of Thermal & Environmental Engineering,vol.46 ,pp. 100-110.

[6] Eckhard B.G., Groll A., Garimella S.V., “Multi-objective optimization of sustainable singleeffect water/lithium bromide absorption cycle” Renewable Energy,2012,vol.46pp. 100110.

[7] Ketfia O., MerzoukM.,Merzouk N.K., “Performance of a Single Effect Solar Absorption System” Energy Procedia,2015,vol.74, pp. 130–13.

[8] Kumar P., Kumar M., Mishra P., “Review of Automobile Air conditioning by Vapour Absorption Utilizing Heat of Exhaust Gases” Journal of Basic and Applied Engineering ResearchPrint Online ISSN: 23500255,2014,vol.1, pp. 114-118.

[9] Mathapati S.S., Gupta M., Dalimkar S., “A Study on Automobile Air-Conditioning Based on Absorption RefrigerationSystem Using Exhaust Heat of a Vehicle”, International Journal of Engineering Research and General Science,2014,vol.2, pp.36-40.

[10] Yaodong W., “ Design and assessment on a novel integrated system for power and refrigeration using waste heat fromdiesel engine”,AppliedThermal Engineering,2015,vol77, pp. 591599.

[11] S.M. Ali , A. Chakraborty, “Using engine exhaust gas as energy for an absorption refrigeration system” Applied Energy,2011,vol.83, pp. 1141–1148.

[12] Alqdah K., Alsaqoor S., Al-JarrahA.,“Design and Fabrication of Auto Air Conditioner Generator Utilizing Exhaust Waste Energy from a Diesel Engine” Int. J. of Thermal & Environmental Engineering,vol.46 ,pp. 100-110.

[13] Eckhard B.G., Groll A., Garimella S.V., “Multi-objective optimization of sustainable singleeffect water/lithium bromide absorption cycle” Renewable Energy,2012,vol.46pp. 100110.

[14] Ketfia O., MerzoukM.,Merzouk N.K., “Performance of a Single Effect Solar Absorption System” Energy Procedia,2015,vol.74, pp. 130–13.

[15] Kumar P., Kumar M., Mishra P., “Review of Automobile Air conditioning by Vapour Absorption Utilizing Heat of Exhaust Gases” Journal of Basic and Applied Engineering ResearchPrint Online ISSN: 23500255,2014,vol.1, pp. 114-118.

[16] Mathapati S.S., Gupta M., Dalimkar S., “A Study on Automobile Air-Conditioning Based on Absorption RefrigerationSystem Using Exhaust Heat of a Vehicle”, International Journal of Engineering Research and General Science,2014,vol.2, pp.36-40.