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Review of Automobile Air-conditioning by Vapour Absorption System Utilizing Heat of Exhaust Gases

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Abstract: *This 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% of total oil consumption. The ultimate goal towards these researches is higher efficiency, lower fuel consumption by improving fuel economy, producing fewer emissions from the exhaust, and utilizing waste heat for running auxiliaries. 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 and coolant and the exhaust gases. Exhaust gases contains around 30% of heat energy. 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. The development in designing alternate system, its commercial viability, future scope and challenges are elaborately considered in this paper.*

1. INTRODUCTION

In last few decades there has been substantial rise in the number of transportation vehicles. According to a study, in 1950 there were about **53** million cars on the world's roads, only four decades later the global automobile fleet is now over **430** million, more than an eightfold increase. This increase has subsequently caused the huge burden on natural resources. Motor vehicles accounts for around 1/3 rd of the total world oil consumption. 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 core ideal of every research work. The I.C engine is the prime mover of these automobile. 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%. This means rest 65% of energy is taken up by exhaust gases and coolant out of which exhaust gases alone consists of 35% 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. Most of the automobile uses vapour compression refrigeration system to air condition the passenger's space or for refrigeration of goods. Over the years VCRS system is refined and it is robust and reliable. But one of the major drawbacks of this system is that it draws considerable amount of power from I.C engine which decreases the overall efficiency of vehicle. It utilizes about 5% of the total energy. Additional load on engine also increases the emission and fuel consumption. Moreover the refrigerants used in VCRS system are mainly HCFCs and HFCs, which are not environmentally friendly. These shortcomings are eliminated in vapour absorption refrigeration system which uses heat energy rather than mechanical energy. Automobile air-conditioning has become an indispensable need. The comfort of the passenger is of utmost priority. The refrigeration is also widely used to preserve perishable goods like vegetables and food items while transporting it to over long distance.

1.1 Working of automotive air conditioning system based on vapour compression system

Vapour compression system consists of following four main components: compressor, condenser, expansion valve and evaporator. This system uses circulating refrigerant which absorbs heat from the space to be cooled and subsequently rejects heat to ambient air. Compressor is driven by belt attached to crankshaft. The low pressure saturated refrigerant enters compressor where it is compressed thereby increasing pressure and temperature of the refrigerant.

The hot vapour refrigerant is routed through condenser. In the condenser, it is cooled by flowing through a coil or tubes. The condenser may be water cooled or air cooled.

Expansion valve may be of capillary tube consisting very thin diameter wire. When the cooled liquid refrigerant passes through expansion valve it undergoes in abrupt pressure reduction. The temperature of the refrigerants is further reduced.

The cooled refrigerant is passed through evaporator coil placed in the space to be cooled. A fan or blower blows the air over the coils, the air passing over coil is cooled which further cools the space. The hot refrigerant from the evaporator is again circulated in the system to repeat the cycle.

1.2 Vapour absorption refrigeration system

VARS system uses heat energy to change the state of the refrigerant. The compressor of the VCRS system is replaced by absorber, generator and a small pump, the remaining components are same.

The working of this refrigeration system is that a mixture of refrigerant and an absorbent (i.e. strong solution) is pumped from the absorber using a small pump to the generator. The generator is the main unit of the whole refrigeration system. This is the place where heat is supplied to the strong solution. Due to the supplied heat to the mixture in the generator the refrigerant is separated from the strong solution and forms vapour. The remaining weak solution flows back to the absorber. The refrigerant is then allowed to pass through a condenser where the heat of the vapour is extracted and the refrigerant temperature decreases. This cooled refrigerant is then passed through an expansion device where during expansion the temperature of the refrigerant falls below the atmospheric temperature. Low temperature and pressure refrigerant is then passed through an evaporator from where the refrigerant absorbs heat and produces refrigerating effect. The refrigerant coming from the evaporator is hot and it is passed to the absorber. The weak solution coming from the generator mixes with the refrigerant from the evaporator in the absorber due to high affinity towards each other , hence forming a strong solution. The strong solution is again pumped into the generator and the cycle repeats itself.

2. COMPARATIVE STUDY OF VAPOUR ABSORPTION AND VAPOUR COMPRESSION REFRIGERATION SYSTEM.

VARS

It uses low grade energy like heat. Therefore may be worked on the exhaust systems from IC engines.

Moving parts are only in small pump, so smooth operation and very less power required. The system can work on lower evaporator pressures also without affecting the c.o.p. There is no effect of reducing the load on the performance. Liquid traces in evaporator do not affect the working much as in VCRS it can damage compressor. Automatic controlling of the capacity is easy.

VCRS

It uses high grade energy like mechanical work.
Moving parts are in the compressor so more tear, wear, and noise. C.o.p decreases considerably with decrease in evaporator pressure. Performance is adversely affected at partial load. Liquid traces in suction line may damage the compressor

Automatic control is difficult.

3. LITERATURE STUDY

Absorption refrigeration was discovered by Nairn in 1777, though the first commercial refrigerator was only built and patented in 1823 by Ferdinand Carré, who also got several patents between1859 and 1862 from introduction of a machine operating on

Ammonia–water (Cheung [1]; Costa [2]; Pereira [3]; Srikhirin [4]). The system went through ups and down. From 1970 onward new alternative were used such as solar energy and waste heat from commercial industries to operate absorption refrigeration system (Horuz and Callander [5]; Varani [6]; Maidment [7]).

From launch of absorption refrigeration system, the pair of ammonia–water has largely been used. Both fluids are highly stable at a wide operating temperature and pressure range. Ammonia has a high enthalpy of vaporization, which is necessary for satisfactory system performance. The system can be used at low temperature, as the ammonia freezing point is -77˚C. Besides, the pair of ammonia–water is environment friendly and of low cost [4]. The system of ammonia–water has as a disadvantage that it requires extra component to trap traces of water. On the other hand, operation above atmospheric pressure is a considerable advantage of this system. Though ammonia–water systems were previously applied to refrigeration and ice production, recent applications are predominantly on air conditioning, for which the pair of water–lithium bromide can also be employed (Chuaa [8]; Costa [2]; Lazarrin [9]).

In the paper ‘Heat recovery from automotive engine’

Hugues L. Talom, Asfaw Beyene[10]; used exhaust gas from a 2.8L V6 internal combustion engine which was used to run a 3 ton absorption chiller, modified for hot gas intake. The experiments conducted on the system, proved that the concept is feasible, and could significantly enhance system performance depending on part-load of the engine. The concept could be used for refrigeration and air conditioning of transportation vehicles.

Wu and Schulden [11] presented a modified Carnot cycle for a heat engine using high-temperature waste heat. The authors adopted the power per heat exchanger surface unit area for performance analysis of the heat engine. The relation between the maximum obtainable specific power and the temperature range in which the high-temperature waste heat engine operates was found.

Koehler [12] designed, built and tested a prototype of an absorption refrigeration system for truck refrigeration using heat from the exhaust gas. The refrigeration cycle was simulated by a computer model and validated by test data. The recoverable energy from the exhaust gas was analyzed for representative truck driving conditions at city traffic, mountain roads and flat roads.

The prototype showed a coefficient of performance of about 27%, but system simulation showed that could be improved by nearly the double. The results indicated the system as an interesting alternative for long distance driving on flat roads.

Zhao[13] studied two combined absorption/compression refrigeration cycles using ammonia and water as the working fluid. The combined cycle with one solution circuit was a conventional absorption chiller with a mechanical compressor, using both the work and heat output from an engine. The authors concluded that the combined cycle with two solution circuits was the best option.

Jiangzhou[14] presented an adsorption air conditioning system used in internal combustion engine locomotive driver cabin. The system consists of an absorber and a cold storage evaporator driven by the engine exhaust gas waste heat, and employs zeolite–water as working pair. The mean refrigeration power obtained from the prototype system was 5 kW, and the chilled air temperature was 18˚C. The authors described the system as simple in structure, reliable in operation, and convenient to control, meeting the demands for air conditioning of the locomotive driver cabin.

Alhusein Inayatallah, [15] designed a simple aqua ammonia absorption system for automobile air conditioning utilizing the exhaust waste heat from a spark ignition engine. Gui [18] studied the feasibility of application of a solid-absorption system using ammonia and chlorides as working pair to automobile air-conditioning system.

Masadeh, Sh. [17] carried out the analysis and investigation of an automobile aqua- ammonia air conditioner using the engine exhaust gases and the desired cooling load from Alhusein and Inayatallah (1994).

A complete system was built and the performance of the system was studied based on the different factors including the temperatures and the exhaust gases flow rate and the engine power. He suggested that the system can be manufactured easily and transferred to the industry and more commercial size recommended to be studied.

Al-Aqeeli1and Gandhidasan [18] .They investigated the feasibility and design of an air conditioning system for automobiles using the Open Cycle absorption System, with LiBr-H2O as the working fluid.

Shekh Nisar Hossain , Saiful Bari [19]: detail study was conducted to utilize exhaust heat from diesel engines to provide additional power using a separate Rankine Cycle (RC). In their research, experiments were conducted to measure the available exhaust heat from a 40 kW diesel generator using two ‘off-the-shelf’ heat exchangers. The effectiveness of the heat exchangers using water as the working fluid was found to be 0.44 which seems to be lower than a standard one. This lower performance of the existing heat exchangers indicates the necessity of optimization of the design of the heat exchangers for this particular application.

Shah Alam [20] proposed a model for utilizing the exhaust waste heat to run automobile air-conditioner In his work three fluid (Ammonia–Hydrogen and Water) vapor absorption systems is used for air conditioning of four strokes, four cylinders passenger car.

The most available studies that conducted the auto air conditioners using waste energy as thermally driven are Robert. and Frosch, [21]. They investigated the automotive air conditioner utilizing the solar and motor waste heat.

Binghadi and Agarwal [22] proposed use of lithium bromide Li.Br –Zn Br as a working fluid using a computer aided analysis of the thermal system.

4. DESIGNING ASPECT

4.1 working fluid combination

Among the most applied working fluids are the pair of ammonia refrigerant–water absorbent (NH_3–H_2O) and water refrigerant–lithium bromide absorbent (H_2O–LiBr). A limitation of the pair of water–lithium bromide is the difficulty to operate at temperatures lower than 0˚C. Besides, lithium bromide crystallizes at moderate concentration and at high concentration; the solution is corrosive to some metals. Moreover, special inhibitors needed to be incorporated to retard system corrosion. (Horuz [11]; Srikhirin. [4]) Ammonia is highly soluble in the water. Both fluids are highly stable at a wide operating temperature and pressure range. Ammonia has a high enthalpy of vaporization, which is necessary for satisfactory system performance. The system can be used at low temperature, as the ammonia freezing point is -77°C.The pair ammonia–water is environment friendly and of low cost . Ammonia is very good solvent of copper, so stainless steel should be used for designing. S.LAKSHMI SOWJANYA conducted thermal analysis on various materials for designing purpose

4.2 Heat load analysis of car

Table 1

Heat load	Amount of heat(kj/hr)
Solar radiation(roof,walls,glasses)	300
Normal heat gain through glass	1200

Normal heat gain through walls etc	4300
Air leakage	1000
Passenger including driver	1200
Total	8000kj/hr or 2.22kj/sec

A rough load estimation of a car suggests that 1 TR air conditioning is sufficient for cooling car. This load calculation has been done for ideal condition. There may be variation due to fenestration or geographical area in which automobile is driven.

4.3 Exhaust gas analysis at different speed

The table 2 consists of different data measured at different engine speed. It can be concluded from the table that the considerable amount of energy is available at exhaust outlet, which is sufficient to power the vapour absorption system. The amount of heat in exhaust gas depends upon the type of automobile. Heavy vehicles like trucks have around 65kw of heat in exhaust gases. So a higher rating of air-conditioning system can be easily designed for heavy vehicle.

Table 2

Throttle Position opening	Engine Speed	Air Pressure	Exhaust Temperatur e	Useful exhaust heat
	rpm	mm of H2O	˚c	KJ/sec
1/4th	3500	7.4	622	3.98
	3000	7.9	605	3.91
	2500	7.2	566	3.5
	2000	5.6	623	3.49
	1500	4.9	582	3.05
half	3500	14.8	669	6.02
	3000	15.9	615	5.74
	2500	12.3	648	5.47
	2000	9.4	595	4.31
	1500	6.8	588	3.61

5. SHORTCOMINGS OF THE DEVELOPED SYSTEM

The engine back pressure is higher because of the more restricted exhaust gas flow area. This caused higher fuel consumption and decrease in performance. The higher fuel consumption was equivalent to a 2% reduction in engine efficiency.

One such difficulty would occur when the vehicle will be at rest or in a very slow moving traffic conditions. In either of these conditions the resulting reduction in heat input to the generator would cause a corresponding drop in the cooling effect of the system. The system developed so far has lower exhaust heat utilization in the generator. The leakage of ammonia possesses threat to the passengers.

6. CONCLUSION

The study confirms that the engine exhaust gas is a potential source of power for vapour absorption system .A dedicated absorption refrigeration system may be able to take advantage of the exhaust gas power availability and provide the cooling capacity required for automotive air-conditioning. Preliminary studied showed that introduction of the absorption refrigeration system ,engine output power was increased and specific fuel consumption was decreased. Overall, carbon monoxide emission was decreased when the absorption refrigerator was installed in the exhaust gas, while hydrocarbon emissions showed an increase. Changes in exhaust components concentration were a consequence of the major modifications in the exhaust system.

Also from the Environmental point of view this system is Eco-friendly as it involves the use of Ammonia as a refrigerant which is a natural gas and is not responsible for ozone layer Depletion

6.1 Future scope

The future development includes the compact design of a heat exchanger capable of extracting the maximum waste heat with minimum pressure loss in the exhaust systems which can be used for commercial production. A detail study of effect of increased back pressure on engine performance and emission will help to utilize the exhaust heat without affecting I.C engine efficiency.

The effect of fluctuations in the cooling capacity caused by variations in vehicle speed will help to optimize the system. The development of alternative energy input while vehicle is stationary. Safety consideration in case of leakage, should be addressed effectively

REFERENCES

[1] Cheung K, Hwang Y, Judge JF, Kolos K, Singh A, Radermacher R. Performance assessment of multistage absorption cycles. Int J Refrig 1996;19(7):473–81.

[2] Costa EC. Refrigeration. 3rd ed. São Paulo: Edgard Blücher; 1988 [in Portuguese].

[3] Pereira JTV, Milanês RLP, Silvério RJR. Energy and exergy evaluation of a water–ammonia absorption refrigeration system. In: Mercofrio – I Mercosul HVACcongress, Porto Alegre, Brazil; 1998.

[4] Srikhirin P, Aphornratana S, Chungpaibulpatana S. A review of absorption refrigeration technologies. Renew Sustain Energy Rev 2001;5(4):343–72.

[5] Horuz I, Callander TMS. Experimental investigation of a vapor absorption refrigeration system. Int J Refrig 2004;27(1):10–6.

[6] Varani CMR. Energy and exergy evaluation of a water–lithium bromide absorption refrigeration unit using natural gas. D.Sc. Thesis. João Pessoa, Brazil:Federal University of Paraíba; 2001 [in Portuguese].

[7] Maidment GG, Zhao X, Riffat SB. Combined cooling and heating using a gas engine in a supermarket. Appl Energy 2001;68:321–35.

[8] Chuaa HT, Toh HK, Ngb KC. Thermodynamic modeling of an ammonia–water absorption chiller. Int J Refrig 2002;25(7):896–906.

[9] Lazarrin RM, Gasparella A, Longo GA. Ammonia–water absorption machines for refrigeration: theoretical and real performances. Int J Refrig1996;19(4):239–46.

[10] Heat recovery from automotive engine: Hugues L. Talom, Asfaw Beyene. Applied Thermal Engineering 29 (2009) 439–444

[11] Wu C, Schulden WH. Maximum obtainable specific power of high-temperature waste heat engines. Heat Recov Syst CHP 1995;15(1):13–7.

[12] Koehler J, Tegethoff WJ, Westphalen D, Sonnekalb M. Absorption refrigeration system for mobile applications utilizing exhaust gases. Heat Mass Transfer 1997;32:333–40.

[13] Zhao Y, Shigang Z, Haibe Z. Optimization study of combined refrigeration cycles driven by an engine. Appl Energy 2003;76:379–89.

[14] Jiangzhou S, Wang RZ, Lu YZ, Xu YX, Wu JY, Li ZH. Locomotive driver cabin adsorption air-conditioner. Renew Energy 2003;28:1659–70.

[15] Alhusein M, Inayatullah G. Automobile Vapor Absorption Air Conditioning System. Journal of Mu'tah for Research and studies 1994; 9: 251-269.

[16] Gui-ping Lin Xiu-gan Yuan Zhi-guang Mei. The Feasibility Study of the Waste Heat Air-Conditioning System for Automobile. Journal of Thermal Scienc1986; 3.

[17] Masadeh. S. Design and Performance of Automobile Aqua-Ammonia A/C System Utilizing Exhaust Waste Heat. Master Thesis, Department of Mechanical Engineering, University of Jordan; 2002.

[18] Al-Aqeeli N, Gandhidasan P. The use of an open cycle absorption system in automobile as an alternative to CFC. Proceeding the 6th Saudi Engineering Conference, KFUPM, Dhahran, December 2002.

[19] Hossain, S. and Bari, S., "Additional Power Generation from the Exhaust Gas of Diesel Engine by Bottoming Rankine Cycle," SAE Technical Paper 2013-01-1639, 2013, doi:10.4271/2013-01-1639.

[20] Shah Alam. Proposed model for utilizing exhaust heat to run automobile air-conditioner. Proceeding of the International Conference on Sustainable Energy and Environment. Bangkok, Thailand, November, 2006.

[21] Robert A. Frosch. Automotive Absorption Air Conditioner Utilizing Solar And Motor Waste Heat, United States Patent 1980; 4:307,575.

[22] Bin Gadhi S. Agrawal R , and Kaushik . Computer Aided Analysis and Thermal Design of a Signal Effect Absorption Unit Using Methanol-LiBr.ZnBr2 Mixture. Proceedings of the International Conference on Refrigeration and Air Conditioning, Amman, 1988.