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Fabrication and Performance Evaluation of Electrolux Refrigeration System Coupled with IC Engine

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Abstract

All the conventional automobiles, thermal power plant, refineries use VCR system for air conditioning purposes. VCRS system utilizes the engine shaft power as input to drive the compressor. We develop a VAR system using Electrolux which is coupled to an IC Engine. IC Engine has an efficiency of about 35-40% which means that only 1/3rd of the energy is converted into useful work and about 60-65% is wasted.In Vapour Absorption Refrigeration system , a physicochemical process replaces the mechanical process of VCRS by using the energy in the form of heat rather than mechanical work.The heat required to run the VARS can be obtained from the Exhaust of the IC Engine.As VARS uses ammonia refrigerant. It cannot be used for domestic purposes. As the future scope , NH3 is replaced by LiBr as refrigerant.

Keywords: Vapour Absorption Refrigeration system, refrigerant, automobiles, Electrolux.

Introduction

Energy efficiency has been a major topic of discussions on natural resources preservation and costs reduction. Based on estimates of energy resources reduction at medium and long terms, it is vital to develop more efficient processes from energy standpoints. Other motivating factors are the continuous optimization of the performance of internal combustion engines and the increasing utilization of air conditioning in vehicles, as it reaches the status of essential need for modern life. Internal combustion engines are potential energy sources for absorption refrigeration systems, as about one third of the energy availability in the combustion process is wasted through the exhaust gas. Thus, use of the exhaust gas in an absorption refrigeration system can increase the overall system efficiency. 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 Electrolux refrigerator.

Literature review

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 between 1859 and 1862 from introduction of a machine operating on ammonia–water (Cheung et al. [1]; Costa [2]; Pereira et al. [3]; Srikhirin et al. [4]). The absorption refrigeration system went through ups and downs, being the antecessor of the vapor compression refrigeration system in the 19th century. By that time systems operating on ammonia–water found wide application in residential and industrial refrigerators. Systems operating on lithium bromide–water were commercialized in the 1940's and 1950's as water chillers for large buildings air conditioning (Costa [2]). Substitution of petroleum-based combustion fuels in the 1970's affected the application of absorption refrigeration, but, at the same time, new opportunities arose, such as usage of solar energy to operate this system (Costa [2]). Increasingenergy costs and other factors has contributed to frequent use of low temperature energy waste from chemical and commercial (supermarket) industries to operate absorption refrigeration systems.

Absorption refrigeration system differs from vapor compression refrigeration system due to utilization of thermal energy source instead of electric energy. In the absorption refrigeration system two working fluids are used: a refrigerant and an absorbent. Among the most applied working fluids are the pair ammonia refrigerant water absorbent (NH_3–H_2O) and water refrigerant–lithium bromide absorbent (H_2O–LiBr). A limitation of the pair water–lithium bromide is the difficulty to operate at temperatures lower than 0 ^{0}C. Besides, lithium bromide crystallizes at moderate concentration, and, at high concentration, the solution is corrosive to some metals and is of high cost (Srikhirin et al. [4]). The system water–lithium bromide operates below atmospheric pressure, resulting in system air infiltration, which requires periodical purge. Moreover, special inhibitors needed to be incorporated to retard system corrosion [2].

From launch of absorption refrigeration system, the pair 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 ^{0}C. Besides, the pair ammonia– water is environment friend and of low cost [4]. The system ammonia–water has as a disadvantage the requirement of extra components. On the other hand, operation above atmospheric pressure is a considerable advantage. Though ammonia–water systems were previously applied to refrigeration and ice production, recent applications are predominantly on air conditioning, for which the pair water–lithium bromide can also be employed

Koehlerdesigned, 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.

Meunier discussed adsorption air conditioning for automobiles as a very challenging possibility for adsorption cooling. The author states that car air conditioning is an ideal solution for sorption systems to be competitive from the global warming point of view, even with low coefficient of performance (COP). The technological difficulties are on the need for light and compact units requiring efficiency improvement and heat transfer intensification in the adsorbers to reduce the size and weight of the units.

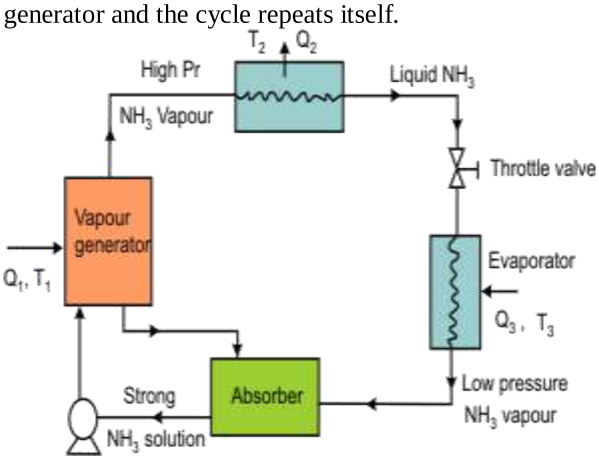
Recently developed and constructed a novel microcombined cooling, heating and power (CCHP) system, based on a two bed silica gel–water adsorption chiller. Using results from numerical simulation the authors found that the cooling capacity and the coefficient of performance (COP) of the chiller were influenced significantly by the average value and variation rate of electricload, as well as the average value of cooling load. The authors recommended the use of a water tank in order to get better performance of the chiller and acceptable start-up time. Also was recommended the use of a cold accumulator for higher performance and system security.

The studies done by AndriAlexioManzela, Jose Ricardo shows :(i) increase in COP (ii) decrease in evaporator temperature (iii) increase in refrigeration effect with respect to time [5].

Vapour absorption refrigeration system

The vapour absorption system uses heat energy, instead of mechanical energy as in vapour compression systems, in order to change the conditions of the refrigerant required for the operation of the refrigeration cycle. The function of a compressor, in a vapour compression system, is to withdraw the vapour refrigerant from the evaporator. It then raises its temperature and pressure higher than the cooling agent in the condenser so that the higher pressure vapours can reject heat in the condenser. The liquid refrigerant leaving the condenser is now ready to expand to the evaporator conditions again.

This refrigeration system consists of a condenser, an expansion valve and an evaporator similar to a Vapour Compression Refrigeration System. But the compressor of the Vapour Compression Refrigeration System is replaced by a generator, an absorber and a small pump. The process of working of this refrigeration system is that a mixture of refrigerant and an absorber (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 through a restrictor in 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 is brought to the room temperature. This cooled refrigerant is then passed through an expansion device where during expansion the temperature of the refrigerant falls below the atmospheric temperature. This cold 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 coming from the evaporator in the absorber due to high affinity towards each other for the two fluids, hence forming a strong solution. The formed strong solution is again pumped into the generator and the cycle repeats itself.



Total equivalent warming potential (TEWI)

The influence of different refrigeration system on climate change is expressed in terms of Total Equivalent Warming Impact (TEWI).The idea of considering both the direct and the indirect contributions from the refrigerant agent and the power generation, respectively, plus the contribution from manufacturing a unit, was developed by the Alternative Fluorocarbons Environmental Acceptability Study (AFEAS) and the US Department of Energy (DOE). The sum of these contributions is called the ''total equivalent warming impact'' (TEWI) of the technology being considered.

TEWI = refrigerant contribution converted toCO_2 + CO_2 from fossil fuel over lifetime of cooling unit + CO_2 equivalent to energy to build unit and produce the refrigerant fluid

TEWI = (GWPxm) + (αxβ)

Where GWP- Global warming Potential

m-Total mass of CFC released

α - Kg of CO_2/kWh

β - Energy consumption of the system in this life

Engine efficiency and associated losses

As the heat content of a fuel is transformed into useful work, during the combustion process, many different losses take place. These losses can be divided into two general classifications: thermodynamic and mechanical. The net useful work delivered by an engine is the result obtained by deducting the total losses from the heat energy input.

Thermodynamic Losses

Losses of this nature are a result of the following: loss to the cooling and lubricating systems; loss to the surrounding air; loss to the exhaust; and loss due to imperfect combustion. Heat energy losses from both the cooling water systems and the lubricating oil system are always present. Some heat is conducted through the engine parts and radiated to the atmosphere or picked up by the surrounding air by convection. The effect of these losses varies according to the part of the cycle in which they occur. The heat of the jacket cooling water cannot be taken as a true measure of heat losses, since all this heat is not absorbed by the water. Some heat is lost to the jackets during the compression, combustion, and expansion phases of the cycle; some is lost (to the atmosphere) during the exhaust stroke; and some is absorbed by the walls of the exhaust passages. Heat losses to the atmosphere through the exhaust are unavoidable. This is because the engine cylinder must be cleared of the hot exhaust gases before the next air intake charge can be made. The heat lost to the exhaust is determined by the temperature within the cylinder when exhaust begins. The amount of fuel injected and the weight of air compressed within the cylinder are the controlling factors. Improper timing of the exhaust valves, whether too early or too late, will result in increased heat losses. If too early, the valve releases the pressure in the cylinder before all the available work is obtained; if too late, the necessary amount of air for complete combustion of the next charge cannot be realized, although a small amount of additional work may be obtained. Proper timing and seating of the valves is essential in order to maintain heat loss to the exhaust at a minimum. Heat losses due to imperfect or incomplete combustion have a serious effect on the power that can be developed in the cylinder. Because ofthe short interval of time necessary for the cycle in modern engines, complete combustion is not possible; but heat losses can be kept to a minimum if the engine is kept in proper adjustment. It is often possible to detect incomplete combustion by watching for abnormal exhaust temperatures and changes in the exhaust color, and by being alert for unusual noises in the engine.

Mechanical Losses

There are several kinds of mechanical losses, but all are not present in every engine. The mechanical or friction losses of an engine include bearing friction; piston and piston ring friction; pumping losses caused by operation of water pumps, lubricating pumps, and scavenging air blowers; power required to operate valves; etc. Friction losses cannot be eliminated, but they can be kept to a minimum by maintaining the engine in its best mechanical condition. Bearings, pistons, and piston rings should be properly installed and fitted, shafts must be in alignment, and lubricating and cooling systems should be at their highest operating efficiency.

In an IC engine, fuel (usually petrol or diesel) is combusted inside the cylinder due to which the piston moves outward and rotates the crank, and hence the engine produces work. In IC engines the combustion of the fuel produces heat, which is converted to mechanical work using the piston and crank arrangement. From the heat produced from combustion of fuel only 30% (approx) of heat is converted into useful mechanical work. The remaining heat energy is wasted into the atmosphere in the form of:

(i) heat carried away by the cooling water,
(ii) heat taken away by the exhaust gases,
(iii) heat carried away by the lubricating oil,
(iv) and, heat lost by radiation.

The cooling water and exhaust gases carry away the maximum amount of heat from the engine, i.e. around 60% (approx). This heat is called the low grade energy of the engine.

Dimensional Specifications

Absorber tank Length : 125 mm
Breadth : 60 mm
Condenser Tube Diameter : 13 mm
Fins Length : 280 mm
Cooling Tube Diameter : 22 mm (outer),
12 mm (inner)
Bypass Line Diameter : 6 mm
Absorber Tube Diameter : 16mm
Cooling coil Bypass tube Diameter: 9 mm

Generator tube Dimensions

Length : 400 mm
Diameter: 15 mm (outer tubing)
: 13 mm (inner tubing)

Engine parameters

Make: Hero Honda:
Model: Splender
Transmission: Four-speed Engine
No of cylinders, n = 1
Capacity, V =98cc
Fuel used = petrol
Air fuel ratio=14.7:1

The experimental procedure

The experimental setup consisting of the engine coupled to the refrigeration unit was put to running mode. For this the 2 stroke engine was cranked by a kicker system. A known quantity of water to be cooled was taken in a measuring jar and poured onto the PVC container fixed around the evaporator tube. Fuel was taken and poured into the fuel tank (measuring unit). It was replenished periodically in about 15 minute’s time as the fuel was used up. The temperature of the water in the PVC container was measured every 15 minutes using the digital thermometer. Similarly the generator input and output temperatures were also measured for the same time interval. This experiment was run approximately for 90 minutes and temperature drop was recorded. Using the recorded and calculated data the necessary graphs and conclusions were constructed.

Observation table

Initial water temperature =33.5 °c
Amount of water in the chiller=250ml

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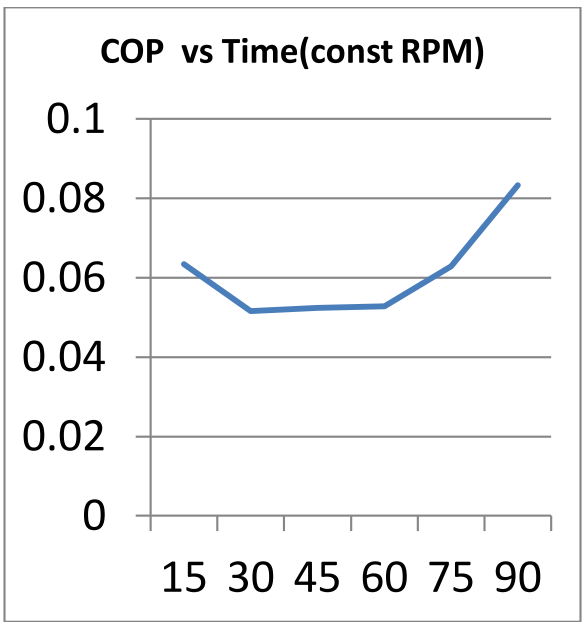
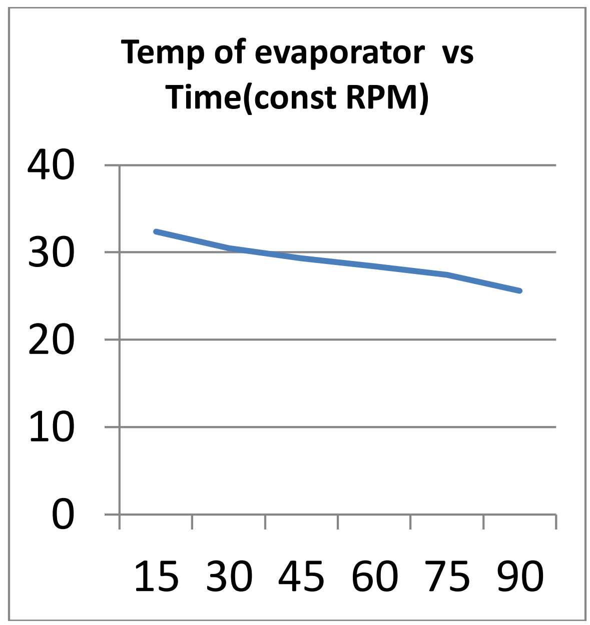
Sl No	Cumulative time(x60 sec)	Generator temperature (°c)		Evaporator temperature(°c)	Fuel consumed(ml)	Refrigeration effect(KW)	Work done(KJ)	COP
		Inlet	outlet					
1	15	100.6	75.9	32.4	60	1.277x10^-3	20.147x10^-3	0.06339
2	30	147.8	100.5	30.5	105	1.7416x10^-3	33.762x10^-3	0.05158
3	45	245.6	201.4	29.3	155	1.6255x10^-3	31.049x10^-3	0.05235
4	60	269.3	236.3	28.4	200	1.1843x10^-3	22.433x10^-3	0.05279
5	75	273.2	240.1	27.4	250	1.4165x10^-3	22.501x10^-3	0.06295
6	90	278.7	250.2	25.6	295	1.587x^10-3	19.051x10^-	0.08329





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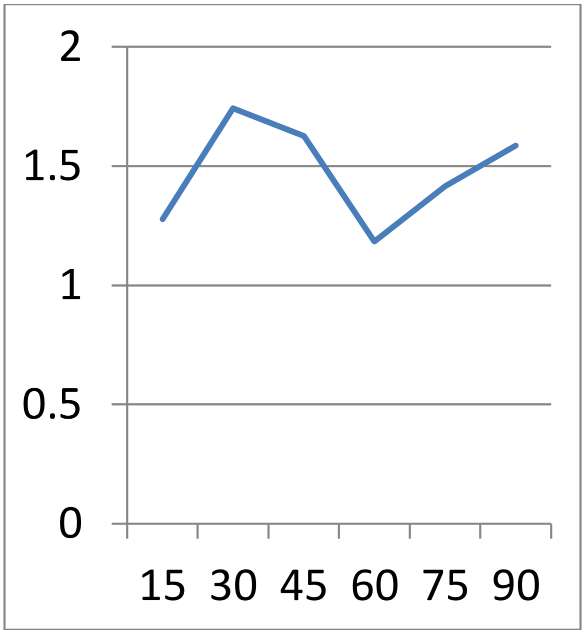

Results and conclusion

A prototype of the refrigerating unit was fabricated and the whole system was coupled with an IC engine. The system was made to run and it was observed that a cooling effect was obtained at the evaporator.

The COP of the system was found to be decreasing in the first 30 minutes then it shows an increase in COP with increase in time. These results agree with the research done by Andri Alexio Manzela, Jose Ricardo. Due to the improper cooling facility given to the air cooled 4 stroke petrol engine the experiment was conducted for 90 minutes, so we could not obtain the actual variation in COP, which was obtained by Andri Alexio Manzela, Jose Ricardo who conducted the experiment for 5-10 hrs.

The temperature of the evaporator was found to be decreasing as expected. The refrigeration effect increased in the first 30 minutes then it shows a decrease in COP with increase in time for the next 30 minutes. After one hour the refrigeration effect shows a gradual increase.

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