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VAPOUR ABSORPTION REFRIGERATION SYSTEM FOR COLD STORAGE & POWER GENERATION IN AUTOMOBILES USING EXHAUST GAS

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Abstract- The possibility of exploiting waste heat from the automobiles has been of great significance in view of ever increasing energy demand and environmental constraints. Waste heat utilization for the production of power and cooling simultaneously helps in reducing problems related to global environment, such as greenhouse effect from CO2 emission due to the combustion of fossil fuels in engines, and the use of chlorofluorocarbon refrigerants which is currently thought to affect depletion of the ozone layer. Thus to overcome these issues we bring out a new system where the maximum utilization of the exhaust energy can be used. In this proposed cogeneration system Li-Br-water absorption system is used along with the thermionic power generation in a mini trucks used for transporting sea foods and cold storages. Required tonne of refrigeration is available using our proposed system. In order to utilize the waste heat coming out from the automobile exhaust, this system is employed. Additional heat available from the generator is used to generate power by thermionic cycle, which is stored in the battery and used for secondary purposes. Results also show that this proposed cogeneration cycle have better exergy and thermal efficiency. The fuel efficiency also increases without much drop in the output power of the engine. This proposed system is economical, eco- friendly and also have good future scope.

Keywords- Exergy, Power, Thermionic cycle, Vapour absorption Refrigeration system, Waste heat.

I. INTRODUCTION

The vapour absorption system is one of the oldest methods of producing refrigerating effect. This system can be used in both domestic and large industrial refrigerating plants. The vapour absorption system uses heat energy, instead of mechanical energy. In the vapour absorption system the compressor is replaced by an absorber, a pump, a generator and a pressure reducing valve. In the system the vapour refrigerant from the evaporator is drawn in to an absorption unit where it is absorbed by the weak solution of the refrigerant forming a strong solution, which is pumped to the generator where it is heated by some external source. During the heating process, the vapour refrigerant then flows into the evaporator and thus cycle is completed.

The vapour absorption refrigeration system needs at least two fluids. One fluid act as a refrigerant while the other as an absorber. The desirable properties of a refrigerant-solvent combinations are the absorber should have greater affinity to absorb the refrigerant, ideal absorbent should remain in liquid state under operating conditions, high boiling point, high specific heat for better heat transfer and low viscosity.
The excess heat available from the generator is used to produce power using Seeback effect. This effect can be used to generate electricity, measure temperature or change the temperature of objects. The thermocouple is well known and has been used extensively over the last 100 years for measurement of temperature and process control. The principle governing the operation of thermocouple devices is the Seeback effect.

II. THE ABSORPTION CYCLE

Fig. 1 below shows the conceptual schematic of an absorption machine using lithium-bromide/water as solution pair. As can be seen in the schematic, the main components of the absorption machine are: desorber (generator), condenser, evaporator, a solution heat exchanger and the absorber.

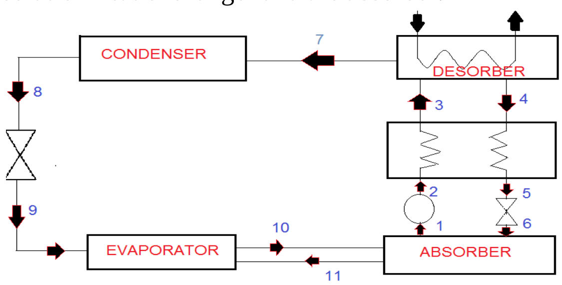

Figure 1. Vapour Absorption Refrigeration System

The process starts when the hot water entering the desorber induces a violent boiling process within the desorber. The boiling takes part of the lithium bromide solution out of the desorber. Furthermore, part of the water escapes as vapour into the condenser and the remaining concentrated solution heads to the absorber. In the condenser, the vapour is condensed to saturated liquid and further expands decreasing the temperature as it goes through the expansion device.

This sub-cooled liquid is finally taken to the evaporator where the cooling effect is obtained and the liquid goes to a superheated water vapour state. Simultaneously the heat released to absorb the vapor is removed by air. The resultant diluted solution then goes back to the evaporator.

With reference to numbering system shown in fig 1,at point (1) the solution is rich in refrigerant and a pump forces the liquid through a heat exchanger to the generator (3). The temperature of the solution in the heat exchanger is increased. In the generator thermal energy is added and refrigerant boils off the solution. The refrigerant vapour (7) flows to the condenser, where heat is rejected as the refrigerant condenses. The condensed liquid (8) flows through a flow restrictor to the evaporator (9). In the evaporator, the heat from the load evaporates the refrigerant, which flows back to the absorber (10). A small portion of the refrigerant leaves the evaporator as liquid spill over (11). At the generator exit (4), the steam consists of absorbent-refrigerant solution, which is cooled in the heat exchanger. From points (6) to (1), the solution absorbs refrigerant vapour from the evaporator and rejects heat through a heat exchanger.

III. SYSTEM ANALYSIS

The determination of thermodynamic properties of each state in the cycle, the amount of heat transfer in each component and flow rates depends on the following input parameters.

Generator temperature T_g (°C)
Evaporator temperature T_e(°C)
Condenser temperature T_c (°C)
Absorber temperature T_a (°C)
Refrigeration load Q_e(kW)

The above set can be determined from the actual running measurements or assumed by a first reasonable estimate to cycle performance. Here pressure drop in components are neglected.

The theoretical COP of Vapour Absorption Refrigeration System is

$$\text{Theoretical COP} = \frac{T_{g-T_c}}{T_g} * \frac{T_e}{T_c - T_e}$$

We consider actual COP= 0.6 * Theoretical COP, with % Li-Br at Absorber = 0.55 and % Li-Br at Generator= 0.65

Capacity of Refrigeration = 15 tonnes

Therefore heat removed (Q_r) from the system = 15 * 210

= 3150kJ/min

For this heat that should be added is 3055.5 kJ/min. This heat is provided from the exhaust gas of the automobile to the generator.

Considering the factors like effectiveness(ε) we take it as 0.8 for heat exchangers. Now this effectiveness would effect the cycle therefore,

$$\text{Total Heat needed} = \frac{Q_{added}}{\varepsilon}$$

A heat exchanger is established between the exhaust manifold and generator of vapour absorption refrigeration system to transfer heat from exhaust gas to the generator, so the required mass flow rate of water through the heat exchanger is obtained from the equation

$$\text{Heat transfer} = m_w c_p (T_{w1} - T_{w2})$$

$T_{W1}$and T_{W2} are the inlet and exit temperature of the water in the heat exchanger.

SECTION	TEMPERATURE	Li-Br concentration
Condenser	30^{o}c	0
Evaporator	5^{0}c	0
Generator	100^{0}c	0.65
Absorber	30^{0}c	0.55

Table 1. Temperature and Li-Br concentration.

IV. POWER GENERATION CYCLE

Seeback Effect

A thermoelectric power generator is a solid state device that provides direct energy conversion from thermal energy (heat) due to a temperature gradient into electrical energy based on "Seeback effect" in figure 2. The thermoelectric power cycle, with charge carriers (electrons) serving as the working fluid, follows the fundamental laws of thermodynamics and intimately resembles the power cycle of a conventional heat engine.

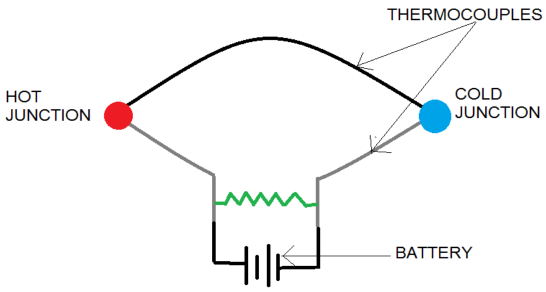

Figure 2. Seeback effect

Thermoelectric power generators offer several distinct advantages over other technologies,

- they are extremely reliable (typically exceed 100,000 hours of steady-state operation) and silent in operation since they have no mechanical moving parts and require considerably less maintenance
- they are simple, compact and safe
- they have very small size and virtually weightless
- they are capable of operating at elevated temperatures; they are suited for small-scale and remote applications typical of rural power supply, where there is limited or no electricity
- they are environmentally friendly
- they are not position-dependent and
- they are flexible power sources.

When a temperature difference is established between the hot and cold junctions of two dissimilar materials (metals or semiconductors) a voltage is generated, i.e., Seebackvoltage.

In fact, this phenomenon is applied to thermocouples that are extensively used for temperature measurements. Based on this Seeback effect, thermoelectric devices can act as electrical power generators. A schematic diagram of a simple thermoelectric power generator operating based on Seeback effect is shown in Fig. (1). As shown in Fig. (1), heat is transferred at a rate of Q_H from a high-temperature heat source maintained at $T_H$to the hot junction, and it is rejected at a rate of Q_L to a low-temperature sink maintained at T_L from the cold junction. Based on Seeback effect, the heat supplied at the hot junction causes an electric current to flow in the circuit and electrical power is produced. Using the first-law of thermodynamics (energy conservation principle) the difference between Q_H and Q_L is the electrical power output W_e . It should be noted that this power cycle intimately resembles the power cycle of a heat engine (Carnot engine), thus in this respect a thermoelectric power generator can be considered as a unique heat engine

V. COMBINED CYCLE

Figure 3. shows the proposed vapour absorption refrigeration system with power generation. Here the vapour absorption process is coupled to Seeback circuit to produce power. Here the exhaust heat is utilized to produce the refrigeration effect and a part of this exhaust gas left out from generator is used to produce the hot junction of the Seeback circuit, thereby producing power. This power is stored in a battery which can be used for secondary purposes.

The exhaust gas coming out from the automobiles is one of the major problems faced by modern world Thus in this proposed cycle we are utilizing the maximum of exhaust energy. The refrigeration effect from the vapour absorption cycle can be used for cold storage purposes. By this we can put a control over the environmental crisis like pollution, global warming etc..

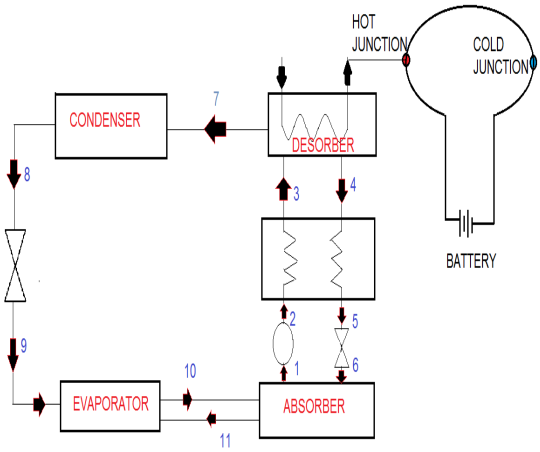

Figure 3. Combined cycle

CONCLUSION

The possibility of exploiting waste heat from the industries has been of great significance in view of ever increasing energy demand and environmental constraints. Waste heat utilization for the production of power and cooling simultaneously helps in reducing problems related to global environment , such as green house effect from CO2 emission due to the combustion of fossil fuels in utility power plants, and the use of chlorofluorocarbon refrigerants which is currently thought to affect depletion of the ozone layer.

In order to utilize the waste heat coming out from the automobiles at a significantly higher temperature (600-700^{o}C) we can adopt this proposed cycle. The automobile waste heat operated combined power and refrigeration cycle, which integrates the LiBr-H2O absorption refrigeration cycle and Seeback cycle. The vapour absorption refrigeration systems powered by waste heat are used in different engineering applications and have several advantages over the well-known compression systems like; simplicity in construction, low capital cost, high reliability, silent operation and very low maintenance cost.

The main objectives of this combined cycle are;

- to utilise the maximum exergy.
- to get better cooling effect.
- to avoid compressor work.
- to produce power for secondary purposes.
- to protect our mother nature from pollution.

Here from this cycle we can produce a cooling effect of 5^{o}C which is suitable for cold storage purposes and thus it can be easily incorporated in heavy automobiles used for such purposes. The power produced can be utilized for other auxiliary purposes of automobiles.

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