Design and Analysis of Solar Vapour Compression Refrigeration System– A Review

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Abstract— In contraction to the conventional energy resources like coal, petroleum etc, it is in need to use renewable energy resources to meet the world energy demand. This is because the conventional energy resources is been constantly depleted by human beings because of urbanization .The renewable energies like wind, water out of that resources evergreen renewable energy is solar energy. This paper deals with the modeling and analysis of a solar powered compression cooling system, using a rectangular plate collector. A 3d model has been developed for compression cooling system to simulate various cycle configurations with changing weather condition. This paper will help than to start the parametric study in order to investigate the influence of overall system performance. In this research we planned to analysis the solar panel for various flow pipe materials in rectangular solar collector. Find made compression with conventional cooling system.

Key words: Air Conditioning, Solar panel, Compressor, Refrigerants

I. Introduction

Solar energy is found to be most inexhaustible source of energy. The power from the sun intercepted by the earth is approximately 1.8 × 1011 MW, which is many thousands of time larger than the present consumption rate on the earth of all commercial energy source. Thus the solar energy can able to supply all the present and future energy needs of the world on continuing basis. Solar energy makes it one of the most promising of the unconventional energy sources. Solar energy can also be utilized for cooling buildings. It is generally known as air-conditioning or refrigeration. Solar cooling appears an attractive proposition due to the fact that when the sunshine is more, then the amount of cooling will be high. This provides thermal comfort for people in hot areas of the world and also for food preservation. It is a motivating factor for doing this project. Out of the various solar air conditioning alternatives, the adsorption system is found to be one of the most promising methods.

A. Conventional Solar Heat Collector

Solar water heating (known as solar thermal) systems capture the free heat from the sun and use it to heat up water for use in the home. It's a simple process:

- panels on your roof absorb heat from the sun – they are known as the collector
- the water in the panels heats up
- this hot water is pumped through a coil in your cylinder which transfers the heat to the water in the cylinder.

Flat plate heat collectors were developed by Hottel and Whiller in the 1950s. It consists of the following parts.

- A dark flat plate absorber
- A transparent cover that reduces heat loss
- A transport fluid to remove heat from the absorber.
- A heat insulating backing.

The heart of a solar collector is the absorber, which is usually composed of several narrow metal strips. The carrier fluid for heat transfer flows through a heat-carrying pipe, which is connected to the absorber strip. In plate-type absorbers, two sheets are sandwiched together allowing the medium to flow between the two sheets. Absorbers are typically made of copper or aluminum.

In water heat panels, fluid is usually circulated through tubing to transfer heat from absorber to an insulated water tank. This may be achieved directly or through a heat exchanger.

B. Solar Water Heating System Circuit

It consists of an absorber plate on which the solar radiation falls after coming through two transparent covers of 4 mm thickness [made of glass]. The space between the covers is 1.5 cm. The absorbed radiation is partly transferred to a liquid flowing through tubes which are fixed to the absorber plate or are integral with it. This energy transfer is the useful heat gain. The remaining part of the radiation absorbed in the absorber plate is lost by convection and re-radiation in the surroundings from the top surface and by conduction through the back and edges. The transparent covers help in reducing the losses by convection and re-radiation in the surroundings from the top surface and by conduction through the back and edges. A liquid flat plate collector is usually held tilted in a fixed position on a supporting structure facing south if located in the northern hemisphere. The absorber plate is usually made from a metal sheet of thickness 1 mm while the tubes are with diameter of 15 mm. They are soldered, brazed/welded or pressure bonded to the bottom of the absorber plate, with pitch of 12 cm. The metal most commonly used for absorber plates and tubes is copper. The header pipes which lead the water in and out of the collector and distribute it to the tubes are made of the same metal as the tubes and are of slightly large diameters. The bottom and sides are insulated by glass wool with a covering of Al foil and has a thickness of 2.5 cm. The whole assembly is contained within a box which is tilted at a suitable angle.

Fig. 1(a): Experimental set-up of Solar Cooling System

The primary components of the refrigeration system are:

1) *Generator*

According to the requirements specified in the design segment, we purchased a 3 litre, mild steel cylinder (it is usually used to carry refrigerants). this cylinder was purchased from gobind refrigerator &air conditioning equipments,balnagar. Operations performed: Drilling : Drilling of four holes of dia 1.5cm at the specifies spots for the inlet and outlets and one hole of dia 2.5 cms for the connection of thermocouple was performed on a vertical drilling machine. Welding: Arc welding was done to weld four 1.5cms and one 2.5 cms mild steel, internally threaded nuts which get mated with the bronze adapters for inlet and outlet connections and one for the thermocouple.

2) *Absorber*

Another 3 litre, mild steel cylinder similar to the generator is used for the purpose of absorber. It was purchased along with the generator. Operations performed: Drilling: Drilling of three holes of dia 1.5cm at the specifies spots for the inlet and outles was performed on a vertical drilling machine. Welding: Arc welding was done to weld four 1.5cms mild steel, internally threaded nuts which get mated with the bronze adapters for inlet and outlet connections.

3) *Condensor*

As specified in the design segment, assuming the natural convection coefficient (h) to be 10W/mK and theoretical mass flow rate(m) to be 8*10^-5 kg/sec, the calculated length for a 1/4th inch mild steel was five meters. The pipe was bent at into several turns with the help of 180degrees bending tool to make it compact and also to enhance the drop in pressure which eliminates the requirements of any throttling device such as a capillary tube.

4) *Evaporator*

A 6mm thick glass container (24x15x6 cms) was ordered n purchased from a glass works shop at r.no 3 BANJARA HILLS. This container is used as an evaporator cabin which is filled with water and the water is expected to be cooled to 10 degrees centigrade as a result of the refrigeration cycle. The same 1/4th inch mild steel tube is wounded in the form of a coil and sent through this evaporator cabin.

5) *Pump*

A special purpose 20w dc pump used in air-conditioning equipment is used in this cycle. The purpose of this device is to pump the solution (strong in water) from the absorber to the generator. This is the only mechanical device being used in the whole system. An adaptor is provided along with this pump to convert the 220v AC power input to 24V DC supply to the pump.

II. LITERATURE REVIEW

SrinivasaRao et al (2013) had made an attempt to produce the refrigeration effect by obtaining the energy from one single flat plate collector, with the help of vapor absorption refrigeration technique as shown in figure 1.

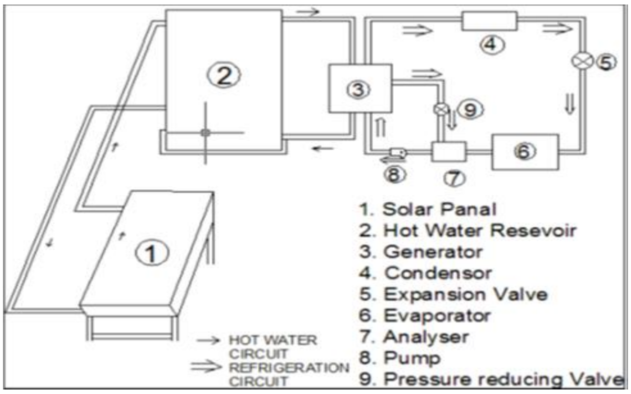

Fig. 2: Experimental set-up of Solar Cooling System by SrinivasaRao et al (2013)

In this a commercial single flat plate water heating system can be used for heating purpose in winter and rainy seasons and cooling effect during summer.

As shown in Figure.2. The experimental set up consists of mainly two circuits: solar water heating system circuit and vapour absorption refrigeration circuit. The authors had observed that as the temperature of hot water supplied to the generator from the single flat plate solar collector increases, the evaporator temperatures at inlet and outlet were decreased. They found that the temperature drop is around the range of 7 to 80C. The maximum COP of the experiment is in the range of 3 to 3.5 and actual COP is found in the range of 0.67 to 0.69. The amount of refrigeration effect of the system is based on the temperature of the hot water supplied to the generator. The additional cost of the refrigeration cycle is very low.

Hassan et al (2012) had conducted an experimental work on solar-driven adsorption cooling system that is able to produce cooling effect continuously for 24-hours of the day. The proposed system is based on the working principle of the constant temperature adsorption cooling cycle.

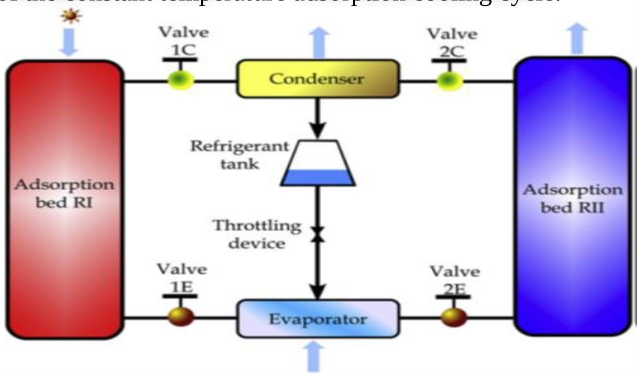

Fig. 3: Diagram of the constant temperature adsorption cooling cyclebyHassan et al (2012)

As shown in Fig. 3. the solar-driven adsorption cooling system for continuous coolingsystemis composed of four heat exchangers, two adsorption reactors RI and RII, a condenser, and an evaporator, two gas regulators connected to the evaporator (1E, 2E), two one-way valves connected to the condenser (1C, 2C), and a throttling device between the refrigerant tank and the evaporator.

The proposed system is composed of two half-cycles which are similar in operation to form a complete cycle. It takes period of a day for each half-cycle. First reactor consists of an isosteric preheating pressurization followed by an isobaric desorption heating and then by an isosteric cooling depressurization process and an isothermal adsorption and pressurization process for the second reactor. The reactor RI is fully charged in the first half-cycle that takes place during the first day with the refrigerant and is separated from both the evaporator and the condenser by closing the valves 1E and 1C. At the time reactor RII is connected to the evaporator and acts as an adsorber, gas regulator 2E is opened. For the second half-cycle the conditions of RI and RII are exchanged. The system he proposed in his paper able to work and produce cold during the 24 hours of the day. Carbon-methanol pair had been used as the working pair in the solar-driven adsorption cooling system.

SnehaPatil et al (2015) had designed a project to establish an alternative eco-friendly refrigeration system for producing a temperature equivalent to conventional refrigeration system. The designed refrigeration system is independent of electric power supply and zero running cost.

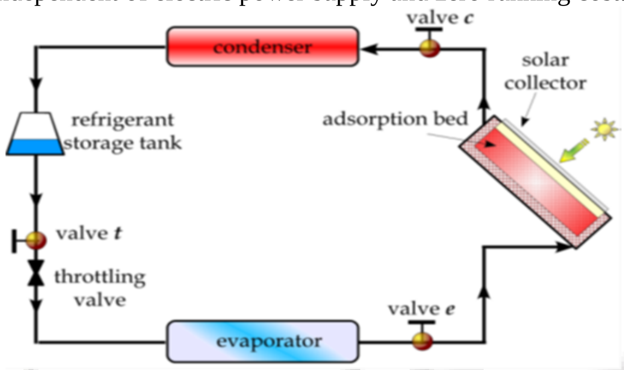

Fig. 4: Schematic diagram of the solar adsorption cooling system by SnehaPatil et al (2015)

The solar adsorption cooling system consist of adsorption container integrated with a flat plate solar collector and contains a porous adsorbent medium. The cycle consists of four processes they were pressurization preheating process at a constant concentration (isosteric heating process), desorption at constant pressure (isobaric heating process), depressurization at constant concentration (isosteric cooling process), andadsorption at constant pressure (isobaric cooling process).

Manojprabhakar et al (2014) modeled and tested refrigeration system, using vapour absorption system.

A. Vapour Compression Cycle

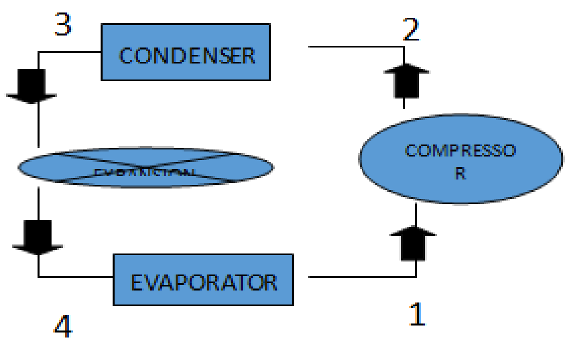

Fig. 5: Vapour Compression Cycle

Saravanan et al (2014)described a new thermodynamic analysis of adsorption refrigeration system. He developed the new mathematical model to analyze the effect of operating parameters like mass concentration ratio, temperature, pressure ratio and refrigerating effect on the performance and it was observed that the impact of mass concentration ratio on performance of the system is highly significant than the other parameters considered for simulation. The model had been focused to prove the importance of mass concentration ratio of adsorbate/adsorbent on the COP of the system.The refrigeration system consist of isosteric heating (1-2),isobaric desorption (2-3), isosteric cooling (3-4),isobaric adsorption (4-1) as shown in figure 5.

The performance of system had been decreased by increasing the ambient temperature.TheCOP of system had been increased by decreasing the ambienttemperature and this reduces the solar collector harvestingarea.

III. SUMMARY OF LITERATURE

The literature review results revealed that the following facts can be considered for the upgradation of the low costsolar air cooling system. The summary of the review has been given as follows:

- Absorption, adsorption, desiccant are the well-developed air conditioning technology.
- Absorption, adsorption cooling can produce chilled water.
- Desiccant cooling can produce the conditioned air for the target space.
- Adsorption system needs two or more adsorbers in order to provide continuous operation.
- Adsorption capacity of silica gel decreases quickly with rise of temperature.
- The amount of refrigeration effect of system is based on temperature of hot water supplied to the generator.
- Carbon methanol pair is the efficient working pair used in solar refrigeration system.
- The coefficient of performance of the system will be low when the refrigerant utilizes lot of energy for cooling system.
- Effective usage of refrigerant energy will able to produce cooling effect for 24-hours a day.
- The coefficient of performance of system can be increased by decreasing the ambient temperature.
- The solar collector harvesting area can be decreased by decreasing the ambient temperature.

IV. CONCLUSION

- The following conclusions can be made from the present investigation
- The Solar flat plate collector Water Heater (SWH) can be effectively used in summer to produce refrigeration effect using vapour absorption refrigeration cycle.
- The amount of refrigeration effect is based on the temperature of the hot water supplied to the generator.
- The maximum drop in the temperature at the evaporator in the present work is estimated to be 7 to 80C.
- The COP (Coefficient Of Performance) of the system is about 0.69 against the maximum COP of the system 3.11.
- The additional cost of the refrigeration cycle is very low.

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