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ENHANCING THERMO-ACOUSTIC REFRIGERATION SYSTEM WITH THE HELP OF VAPOUR ABSORPTION REFRIGERATION SYSTEM

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Abstract

This thesis will deal with the modification required to thermo acoustic refrigerator to increase its COP, so that it can be used on daily basis. The manufacturing will be explained along with the reasons for using specific modification for better performance. The setup consists of 3 units including thermo acoustic refrigerator, a cooling tower and Vapour absorption system. It further also explains the manufacturing of every single unit.

I. Introduction

The temperature differential had been observed since 1850 from acoustic devices but it's been two centuries and there is neither current working project nor any application of acoustic devices in refrigeration process[12]. Thermo acoustic refrigerator are systems which utilizes the sound energy to transfer heat. The refrigerator mainly consists of a loudspeaker connected with resonating tube at one end and resonator at other end. A stack of parallel plates is installed between two heat exchangers in the resonating tube. The resonating tube is filled with fluid that act as a medium at some

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pressure. The acoustic power produces a thermal interaction between heat exchangers and stacks, generating a heat pumping process [1].

On the other hand Vapour absorption refrigeration system uses latent heat from phase change of ammonia to transfer maximal heat from evaporator to condenser [5].

In this paper the design and modification procedure of a thermo acoustic refrigerator with the help of vapour absorption system and cooling tower to increase the COP of whole system is reported. The thermo acoustic hybrid refrigerator constructed on the basis of design procedure given in this paper, has operated properly.

II. Design Strategy

The whole system consists three different systems which are constructed separately and later connected with tubes running refrigerant to transfer heat. The three units are- Thermo acoustic refrigerator, Vapour Absorption refrigeration system, Cooling Tower.

Thermo acoustic refrigerator start by design of heart of the cooler, that is stacks. The ratio of the heat transferred through stacks and the acoustic power used is the coefficient of performance of stacks. The expression of Coefficient of performance is lengthy and complicated but Tijani, Zeegers and Waele worked through equation in their paper and make it easy by using dimensionless independent variables [1].

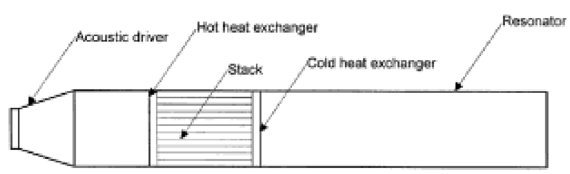

Figure 1. Thermo Acoustic refrigerator.

The Cooling Tower is the system which is connected to the hot heat exchanger of the thermo acoustic refrigerator. This system uses water as refrigerant. The cooling tower consists of sprinkles which transfer water to container and a pump further transfer the water to the hot heat exchanger and then cycle repeats. The water droplets take heat from other droplets and vapourised in the air and a fan connected above it release the vapour into the atmosphere and releasing the heat from system to surroundings.

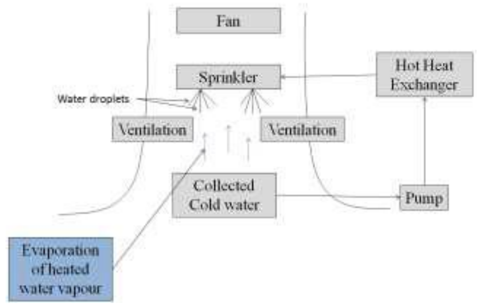

Figure 2. The block diagram of Cooling Tower.

The Vapour absorption refrigeration system uses ammonia as refrigerant and uses heat from manual source or waste heat sink to convert ammonia into vapour. The vapour ammonia absorbs latent heat as well as sensible heat when is flowing in the evaporator. The condenser of Vapour absorption refrigerator is replaced by cold heat exchanger of Thermo acoustic refrigerator. The heat coming from evaporator in VARS is absorbed with the help of Thermo Acoustic refrigerator and the heat is transferred from hot heat exchanger to cold heat exchanger and Cooling tower pumps the heat from Thermo Acoustic refrigerator to surroundings [5].

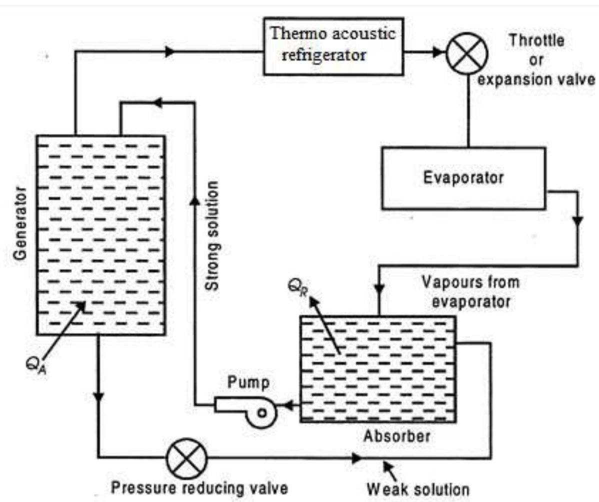

Figure 3. Vapour absorption refrigeration system modification.

III. Literature Survey

Tijani, Zeegers and Waele published most papers on working [3], design [1] and performance [1] of the thermo acoustic refrigerator. They even published the whole paper on sole components like stacks [9] etc. The calculation they have done is used in this paper in finding COP [1], length of many components like heat exchangers, resonating tube, stacks [1] etc.

Olson and Swift wrote a paper about dimensionless parameters [2] for Thermoacoustic devices. Their research was further used in thermo acoustic refrigerators by Tijani, Zeegers and Waele to make the equation for calculating COP simple and compact [1].

Mohd Aziz Ur Rahaman, Md. Abdul Raheem Junaidi, Naveed Ahmed, Mohd. Rizwan published the paper explaining the fabrication and working of Vapour absorption refrigeration system [5].

Mahmoud A. Alamir & Ahmed A. Elamer published the paper explaining which power input is most efficient in thermo acoustic refrigerator [4].

Luke Zoontjens, Carl Howard, Anthony Zander and Ben Cazzolato discussed the difference in efficiency and cost of thermo acoustic devices and vapour using devices. It helps in comparing and using equipments of each other [6]. T. Vijayaraj, M. Swathika, T. Vinithrabanu, M. Durga used a PVC pipes in making the resonating tube of the thermo acoustic refrigerator [7].

IV. Design Choices

The Coefficient of performance of the whole system will be different from COP of Thermo acoustic refrigerator. For experiment purpose cooling power is chosen 4W.

4.1. Working Medium

The working medium or the gas which transfers the heat is chosen Helium. Helium is cheap and has high heat carrying capacity and also helium is a noble gas [1].

4.2. Average Pressure

Since the higher pressure gives higher power density hence higher cooling power but higher pressure makes it difficult to pass the small stacks plate spacing. So after taking these effects into account, the pressure is taken 10bar. Furthermore effect due to pressure is discussed elsewhere [1].

4.3. Stack material

The stacks should have higher heat carrying capacity than the working medium i.e. Helium. Mylar has low heat conductivity and has high heat carrying capacity and furthermore it is cheap [1].

4.4. Frequency

Frequency is the linear function of power density but has inverse effect on stack with very small plate spacing. Balancing the effects of these two, frequency of 400Hz is used [1].

4.5. Resonating Tube

The resonating tube should withstand the dynamic pressure (i.e. more than average pressure) during working process. So PVC pipes are chosen for resonating tube. PVC pipes can withstand high pressure and are insulated to heat. For further insulation purpose thermocol coating is done over the PVC pipe [7].

4.6. Design of Resonating Tube

Tijani, Zeegers and Waele calculated in their paper, for 4W power input, the resonating tube should have a diameter of 4cm and length of 40cm for maximum efficiency. The calculations are not given in this paper [1].

4.7. Design of Stacks

There are many types of stacks- parallel plate, cylindrical plates, etc. But according to difficulty and less required equipment, parallel plates stacks were used. The stacks of length 8.5cm are placed at the distance of 4.2cm from the acoustic driver [1].

4.8. Heat Exchangers

There are two exchangers installed on the resonating tube-Hot heat exchanger and Cold heat exchanger.

4.8.1. Cold Heat exchangers

The heat exchanger is in direct contact with the cold side of thermo acoustic refrigerator and takes all heat necessary from the system to the thermo acoustic refrigerator. Tijani discussed in his research that displacement of the gas at the cold heat exchanger i.e. Helium, corresponds to optimum length i.e. given by [1]-

$$x = \frac{u}{w} - \frac{p}{wq}\sin(kx).$$

And they calculated that the optimum length of cold heat exchanger should be about 3mm for these attributes. Furthermore calculations and effects due to parameters of displacement is given elsewhere. The 1.5mm copper tubes is coiled over heat exchanger for maximal heat transfer[1].

4.8.2. Hot Heat exchangers

Since the hot heat exchanger has to remove twice the heat supplied by cold heat exchanger, the length of heat exchanger [1] should be twice i.e. 6mm.

4.9. Resonator

In thermo acoustic refrigerator, either conical tube after resonating tube is used as resonator or an electric resonator. The electric resonator is used our system [7].

4.10. Acoustic driver

Audio amplifier with double IC is used. Power output for driver is 4W to 8W.

4.11. Design of Vapour absorption refrigeration system

The Condenser is only replaced with Thermo acoustic refrigerator and all other units of Vapour absorption refrigeration system are same. Design of components of VARS are-

4.11.1. Generator

In a 3 Litre mild steel cylinder 4 holes of dia 1.5cm at the specifies spots for the inlet and outlets and one hole of dia 2.5cms for the connection of thermocouple [5].

4.11.2. Absorber

Another 3 litre mild steel cylinder similar to the generator, drilled of three holes of dia 1.5cm at the specifies spots for the inlet and outlets [5].

4.11.3. Evaporator

Aluminium pipes are coiled on the area of 10x10cm square for 1 Litre closed container made of thermocol [5].

4.11.4. Pump

A 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 [5].

4.11.5. Pipes

PVC Pipes of 1.5mm in inner diameter are used to connect different units [5]

V. Conclusion

The modification and design for enhancing thermo acoustic refrigerator has been discussed. The COP of the thermo acoustic refrigerator as a acoustic driver as power input and useful cooling is taken from thermocouple connected to cold heat exchanger, is found 1.3. The COP of only Vapour absorption refrigeration system is found to be 0.7. The COP of whole system as a heat given to the generator as power input and useful heat is observed from evaporator without cooling tower, is found 0.5. And at last the COP of whole system including cooling tower is found to be 1.1. The optimization and effects due to it has been discussed.

References

[1] M. E. H. Tijani, J.C.H. Zeegers and A.T.A.M. de Waele, Design of thermoacoustic refrigerators, Cryogenics 42 (2002), 49-57.

[2] J. R. Olson and G. W. Swift, Similitude in thermoacoustic, J. Acoust Soc Am 1994; 95: 1405-12.

[3] M. E. H. Tijani, J. C. H. Zeegers and A. T. A. M. de Waele, Construction and performance of a thermoacoustic refrigerator, Cryogenics 42 (2002), 59-66.

[4] Mahmoud A. Alamir and Ahmed A. Elamer, A compromise between the temperature difference and performance in a standing wave thermoacoustic refrigerator, 2018.

[5] Mohd Aziz Ur Rahaman, Md. Abdul Raheem Junaidi, Naveed Ahmed and Mohd. Rizwan, Design and Fabrication of Vapour Absorption Refrigeration System, IJMER ISSN: 2249-6645, September 2014.

[6] Luke Zoontjens, Carl Howard, Anthony Zander and Ben Cazzolato, Feasibility Study of an Automotive Thermoacoustic Refrigerator Proceedings of ACOUSTICS 2005.

[7] M. Vijayaraj, Swathika, T. Vinithrabanu and M. Durga, Application Of Thermoacoustic Effect To Cooling Of Air Using Acoustic Waves, IJARIIE-ISSN(O)-2395-4396 2017.

[8] Satish Sonwane, Saurabh Karokar, Rajjat Satpute, Rohan Parate, Ritesh Giri and Rahoul Chitare, Design, Fabrication and Analysis of Thermo- Acoustic Refrigeration System, IJARIIE-ISSN(O)-2395-4396 2017.

[9] M. E. H. Tijani, J. C. H. Zeegers, A. T. A. M. de Waele, The optimal stack spacing for thermo acoustic refrigeration.

[10] Kuldeep I. Solanki, Effect of Working Gases and Stack Material on A Thermoacoustic Refrigerator ISSN (online): 2349-6010.

[11] P. S. Bhansali, P. P. Patunkar, S. V. Gorade, S. S. Adhav and S. S. Botre, An Overview Of Stack Design For A Thermoacoustic Refrigerator eISSN: 2319-1163 | pISSN: 2321-7308.