Design, Fabrication and Analysis of Thermo-Acoustic Refrigeration System – A Review

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Abstract - Thermo-acoustic refrigeration is an environmental friendly technology. It is use as a working fluid like air or Noble gases as a refrigerant. Its biggest advantage is that they do not use harmful gas as a refrigerant and pollutant free method of providing refrigeration. For the safety of the environment, it is necessary to avoid the use of environmentally hazardous refrigerants by developing new alternative refrigeration technologies such as Thermo-acoustic Refrigeration System. This paper describes the variation of hot end temperature and the temperature difference between the different stack ends with the various parameters like frequency, mean pressure. This paper explored the basic principles of thermo acoustic refrigeration, combined with an understanding of the underlying thermodynamics, the model enables us to spread awareness of the visibility of thermo acoustic devices as refrigerator. Thermo acoustics is a field that combines thermodynamics, fluid dynamics and acoustics. In thermo acoustics it is possible to construct thermodynamic engines, prime movers and heat pumps which respectively use heat to create work and use work to create or move heat. The only disadvantage of this thermo-acoustic refrigeration is it has low C.O.P compare to other conventional cooler. But most efficient system are tried to be made. Lots of research is going on in this area.

Key Words: Refrigerant, Stacks .

1.INTRODUCTION

Just by using the power of sound the thermo-acoustic refrigeration system can be able to reduce the cost of refrigeration as well as to reduce the environmental hazard. In the recent years the induction of thermo-acoustic technology has been used for the development in the field of non conventional energy. Modern thermo-acoustic systems are majorly based on linear thermo-acoustics models. This system involves no adverse chemicals or environmentally unsafe elements and is also capable to utilize waste heat coming out from the gas in any heat pump or other heat engine to produce acoustic power. Thermo-acoustics deals with the conversion of heat energy to sound energy and vice versa. There are two types of thermo-acoustic devices: thermo-acoustic engine (or prime mover) and thermo-acoustic refrigerator. In a thermo-acoustic engine, heat is converted into sound energy and this energy is available for the useful work. In this device, heat flows from a source at higher temperature to a sink at lower temperature. In a thermo-acoustic refrigerator, the reverse of the above process occurs, i.e., it utilizes work (in the form of acoustic power) to absorb heat from a low temperature medium and reject it to a high temperature medium.

Thermo-acoustic refrigerator, which does not use any environmentally-unfriendly refrigerants like CFCs and HFCs. Instead, it depends upon the power of sound to generate oscillations required to compress the working gas. The process of refrigeration means the cooling the desired space and maintaining the temperature below the ambient temperature. Acoustics deals with study of sound production, transmission, and effects. Thermo-acoustic deals with thermal effects of the sound waves and the interconversion of sound energy and heat. Sound waves travel in a longitudinal fashion. They travel with successive compression and rarefaction of the medium in which they travel (gaseous medium in this case). This compression and expansion respectively lead to the heating and cooling of the gas. This principle is employed to bring about the refrigeration effect in a thermo-acoustic refrigerator.

The efficiency of the thermo-acoustic devices is currently lower than that of their conventional counterparts, which needs to be improved to make them competitive. In addition, other considerations for a competitive thermo-acoustic device are low cost, high reliability, safety, compactness and ease of mass production.

2. LITERATURE REVIEW

Jinshah B S, Ajith Krishnan R, Sandeep V S [1] completed theoretical, numerical and experimental studies to identify optimum operating conditions for the design, fabrication, and operation of a thermo-acoustic refrigerator. They conclude that a thermo acoustic refrigerator is fabricated with readily available materials. The COP can be improved by replacing working fluid air by some inert gas like helium and also by using pressurized gas instead of using it at the ambient condition. And they suggest that to increase the COP use different Stack materials, different size and shape of the resonator column and modification of the stack design.

M.E.H. Tijani& J.C.H. Zeegers [2] discussed the manufacturing procedure of a thermo acoustic refrigerator. He described the construction of the different parts of the refrigerator in detail. The system has been assembled and first performance measurements have been done. The measurements show that the system behaves very well as expected. A low temperature of 65 0C is achieved. The refrigerator is used to study the effect of some important thermo-acoustic parameters, such as the Prenatal number using binary gas mixtures, and the stack plate spacing.

S. Balonji , L. K. Tartibu , T. C. Jen [4] simulated standing wave thermo-acoustic refrigeration model using DeltaEc software (Design Environment for Low-Amplitude Thermo-acoustic Energy Conversion) and their performance evaluated in terms of relative coefficient of performance by varying the geometrical configuration of ceramic substance used as stack in TAR namely the Diameter, the Length and the Position.

Normah Mohd-Ghazali , Mahmood Anwar , Nurudin H.M.A. [5] Settar performed an experiment and conclude that, Thermo-acoustic cooling have been achieved quite simply without any refrigerants or use of a compressor under atmospheric conditions. Although the temperature drop below ambient was small, the clean technology poses as a potentially attractive alternative to the conventional system in view of the increasing concern over the degradation of the environment caused by refrigerants from the cooling industries. Further studies into the control and reliability of thermo-acoustic systems could make them comparable to the available systems even for specific purposes if not for general applications.

Mehul Parekh [3] conclude, after doing this Research project that there is better green way of refrigeration which gives Carnot efficiency similar or more than current refrigerators. So it is time to adopt new, eco-friendly and better way of refrigeration.

Artur J Jaworski and Xiaoan Mao [6] research on Development of thermo-acoustic devices for power generation and refrigeration. Firstly, to develop an early demonstrator of a low-power electricity generator (to deliver approximately 10–20W of electricity). This was to be based on the concept of using low-cost materials, working fluids and linear alternators suitable for deployment in rural areas of developing countries. Secondly, to develop a demonstrator of a combustion driven thermo-acoustic cooler for storage of vital medical supplies in remote and rural areas where there is no access to electricity grid. And they conclude that Firstly, the process of developing a working prototype of the combustion- driven thermo-acoustic electricity generator capable of achieving 18W of electrical power output. The work described had to address many design issues including a suitable thermo-acoustic engine topology and control measures. Secondly, the presented work included a demonstrator of a thermo-acoustic cooler for storage of vital medical supplies in remote and rural areas where there is no access to grid electricity. This has been driven by electrical heat input, but given the success of the combustion driven electricity generator it is only a matter of time to develop suitable heat exchangers for heat input from combustion processes.

Jonathan Newman, Bob Cariste, Alejandro Queiruga, Isaac Davis, Ben Plotnick, Michael Gordon, and Sidney San Martín [8] show that their device worked as a proof of concept device showing that a thermo-acoustic device is possible and able to cool air. If they were able to build the device with better materials, such has a more insulating tube, they might have been able to get better results. In order to create working refrigerator they probably would have to attach a heat sink to the top of the device, thus, allowing the excess heat to dissipate to the surroundings. However, their device did demonstrate that thermo-acoustic device have the ability to create and maintain a large temperature gradient, more than20 degrees Centigrade, which would be useful as a heat pump.

Mohamed Gamal Mekdad , Abdulkareem Sh. Mahdi Al-Obaidi [12] studied the effects of some design parameters such as wave patterns, frequency, stack position and heat exchanger of thermo-acoustic refrigerator system. They conclude that sine wave gives the highest temperature difference and adding heat exchanger improves the total performance of Thermo-acoustic Refrigeration.

3. CONCLUSIONS

The Thermo-acoustic Refrigeration System consists of no moving parts. Hence the maintenance cost is also low. The system is not bulky. It doesn't use any refrigerant and hence has no polluting effects. All literature review revels that the stack is heart of the thermo-acoustic refrigeration system and the work or research conducted on stack is only regarding to its location in resonator and its length but there is still lack of ideal model of stack and effect of working fluid (gas) on it. So, aim of this research is to improve the performance of thermo-acoustic refrigerator by analyzing the parameters or factor which affects the performance of thermo-acoustic refrigerator trying to improve the performance of thermo-acoustic refrigerator by changing the various parameter and studying their effect on thermo-acoustic refrigerator. Experimental investigations of thermo-acoustics refrigerator with compressed air at different charging pressures with use different stack material and finding the best combination of stack material for creating maximum temperature difference across the stack.

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REFERENCES

[1] Jinshah B S , Ajith Krishnan R, Sandeep V S . " Study on Standing Wave Thermo-acoustic Refrigerator made of Readily Available Materials". International Journal of Scientific and Research Publications, Volume 3, Issue 7, July 2013 ISSN 2250-3153 .

[2] M.E.H. Tijani , J.C.H. Zeegers . "Construction and performance of a thermo-acoustic refrigerator". Design of Thermo-acoustic Refrigerators. Cryogenics, Volume 42, Issue 1, Pages 49–5 , January 2002.

[3] Mehul Parekh. "Research Project Report Green Refrigeration " International Journal of Advancements in Research & Technology, Volume 2, Issue 8, August-2013 ISSN 2278-7763.

[4] S. Balonji , L. K. Tartibu , T. C. Jen "Performance Evaluation of Ceramic Substraction for Cooling Application in Thermo-Acoustic Refrigeration" International Journal of Sustainable Materials Processing and Manufacturing, Vol. 7, pp. 131-137, January 2017.

[5] Normah Mohd-Ghazali , Mahmood Anwar , Nurudin H.M.A. Settar "Thermo-acoustic Cooling with No Refrigerant " International Journal of Technology, (2011) 3: 234-241 ISSN 2086-9614.

[6] Artur J Jaworski and Xiaoan Mao "Development of thermo-acoustic devices for power generation and refrigeration" International Journal of Power and Energy, pp. 227(7) 762–782.

[7] Tong Huana,b, Hu Jianyinga, Zhang Limina, Luo Ercanga, "Experimental study of an acoustic resonant cooling system " 25th International Cryogenic Engineering Conference and the International Cryogenic Materials Conference in 2014, ICEC 25–ICMC 2014, Physics Procedia 67 (2015) , pp. 445 – 450.

[8] Jonathan Newman , Bob Cariste , Alejandro Queiruga , Isaac Davis, Ben Plotnick , Michael Gordon , and Sidney San Martín , "Thermo-acoustic Refrigeration GSET Research Journal" 2006.

[9] P Yang, M Fang, Y.W Liu, "Optimization of a phase adjuster in a thermo-acoustic stirling engine using response surface methodology" The 6th International Conference on Applied Energy – ICAE2014, Energy Procedia 61 (2014), pp. 1772 – 1775.

[10] Nor Atiqah Zolpakar , Normah Mohd-Ghazali , Robiah Ahmad, "Experimental investigations of the performance of a standing wave thermo-acoustic refrigerator based on multi-objective genetic algorithm optimized parameters" Applied Thermal Engineering 100 (23 February ,2016), pp. 296–303.

[11] Matthieu Gu_edra, Flavio C. Bannwart, Guillaume Penelet, Pierrick Lotton, "Parameter estimation for the characterization of thermo-acoustic stacks and regenerators" Applied Thermal Engineering 80 (4February,2015), pp. 229-237.

[12] Mohamed Gamal Mekdad , Abdulkareem Sh. Mahdi Al-Obaidi, "Design and Analysis of A Thermo-Acoustic Refrigerator" International Journal of Advancements in Research & Technology, Vol-3 August 2013 .