International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 07 Issue: 04 | Apr 2020 www.irjet.net p-ISSN: 2395-0072

THERMOACOUSTIC REFRIGERATOR

[1]Prof. Zankar Yadav, [2]Swapnil Macwan, [3]Saumya Patel, [4]Raghav Prajapati, [5]Shubham Prajapati

[1]Assistant Professor, Department of Mechanical Engineering, Indus Institute of Technology and Engineering, Ahmedabad, Gujarat, India.
[2345]UG Student, Department of Mechanical Engineering, Indus Institute of Technology and Engineering, Ahmedabad, Gujarat, India.

Abstract

Thermoacoustic Refrigerators utilize acoustic force for producing cold temperatures. Advancement of fridges dependent on thermoacoustic innovation is a novel answer for the current day need of cooling, without causing ecological perils. With included focal points like negligible moving parts and nonappearance of CFC refrigerants, these gadgets can accomplish low temperatures keeping up a smaller size. The current work portrays a top to bottom hypothetical investigation of standing wave thermoacoustic coolers. This comprises of nitty gritty parametric investigations, transient state examination and a structure utilizing accessible recreation programming. Structure and development of a thermoacoustic cooler utilizing a financially accessible electro-dynamic engine is likewise introduced.

Key Words: Thermoacoustic, Acoustic waves, Resonance, Temperature gradiant

1.INTRODUCTION

Refrigeration in thermodynamics refers to a cycle in which heat is pumped out of a system by doing work on it. Conventional refrigerators use a working fluid that absorbs the heat out of a chamber by using phase transitions. Thermoacoustic refrigeration uses sound waves to transfer heat from one area to another; thereby carrying heat away from a system to an exhaust.

1.1 Acoustics

Thermoacoustics is the interaction between heat and sound. It explains how energy in form of heat can be converted to sound or how sound waves can be used to generate cold temperatures. The pressure and displacement oscillations in a sound wave are accompanied by temperature oscillations. In medium like air at STP and pressure amplitude of ordinary conversation (~ 60 dB), the magnitude of temperature oscillations is about 10-4 C and go undetected by human senses. Working at high pressure amplitudes, the thermal interaction of sound waves with a different medium, a solid for instance can result into sufficiently large amount of heat exchange between the fluid and the solid.

1.2 History

The impacts of thermoacoustics have been watched for a considerable length of time. In particular, glassblowers could hear the sounds made by hot vitality changing over to acoustic vitality while employing a temperature change to hot glass bulbs. Nikolaus Rott and different researchers, for example, Lord Rayleigh, begat "thermoacoustics" as it became comprehended that hot and acoustical energies could change between one another. In any case, it wasn't as of not long ago that this property has been investigated for conceivable building applications which utilize its standards.

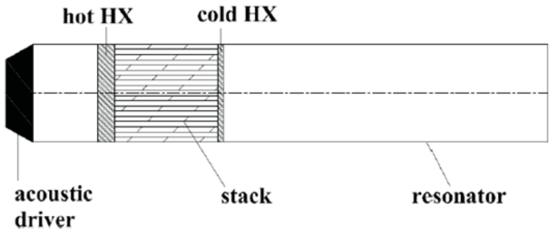
Heat can be produced from sound waves. The concept of “thermoacoustic” forms naturally when thinking about sound and temperature. Both phenomena involve the oscillation of particles. Sound is a pressure wave that transfers kinetic energy from one air molecule to the next using compression and expansion of the medium; and, temperature measures average kinetic energy of particles in a volume. By manipulating sound waves, it is fairly simple, at least in principle, to produce heat.

Since the mid 1980's, places like Los Alamos National Laboratory have been leading tests with expectations of making a gadget that has inactive acoustical-staging instruments. The examination proceeded through crafted by Greg Swift and others whose work was later utilized by M. Tijani and others to build up a down to earth cooler. In 2004, Pennsylvania State University researchers Robert Smith, Steven Garret and Matt Poese built up a working fridge for Ben and Jerry's Ice Cream.

Today, thermoacoustic refrigerators are being researched for their practicality and because they’re environmentally friendlier than conventional refrigerators because of their chemical independence.

2. THERMOACOUSTIC REFRIGERATOR

A thermoacoustic refrigerator pumps heat from low temperature to high temperature region using energy of sound waves. Schematic of a thermoacoustic refrigerator is shown in Figure.



Schematic of a thermoacoustic refrigerator.

The source of acoustic energy is called 'acoustic driver' which can be a loudspeaker. The acoustic driver emits sound waves in a long hollow tube filled with gas at high pressure. This long hollow tube is called 'resonance tube' or simply 'resonator'. The frequency of the driver and the length of the resonator are chosen so as to get a standing pressure wave in the resonator. A solid porous material like a stack of solid plates is kept in the path of sound waves in the resonator.

Due to thermoacoustic effect heat starts to flow from one end of stack to the other. One end starts to heat up while other starts to cool down. By controlling temperature of hot side of stack (by removing heat by means of a heat exchanger), the cold end of stack can be made to cool down to lower and lower temperatures. A refrigeration load can then be applied at the cold end by means of a heat exchanger.

'Thermoacoustics' is a 'green' and another innovation. The working mode of TAR is a latent gas. There is no need of ordinary refrigerants like CFCs that posture risks to the earth. TAR has negligible moving parts and no valves to control liquid stream. When planned effectively, they require extremely less support. Due to utilization of acoustic force, the weight contrast between which a TAR works is little. This implies TAR can discover massive application where clamor or vibration can't go on without serious consequences. Other than this, they have no nearby resiliences and can be manufactured from effectively accessible materials.

Table -1: Parts and Materials

Parts and Materials			
Sr. No.	Parts	Qty	Material
1	The Resonator	1	Glass tube
2	TheStack	1	Aluminium foil
3	Speaker	1	
4	Amplifier	1	
5	Frame	1	Mild Steel
6	Electric Circuit	1	
7	Temperature Sensor	1	

3. Design considerations

This work deals with the design and development of the thermo acoustic refrigerator. The linear thermo acoustic theory will be used for the design analysis. Due to the large number of parameters, a choice of some parameters along with a group of dimensionless independent variables will be used.

(1). Acoustic Driver

The total acoustic power used by the refrigerator is provided by an acoustic driver (speaker). A significant portion of this power is used to pump heat in the stack and the rest is dissipated in different part of the refrigerator. A higher performance of the driver leads to a higher performance of the whole refrigerator system. The acoustic driver converts electric power input to the acoustic power. The most common loudspeaker is of electro dynamic type which uses copper wires and permanent magnet. A Loudspeaker with the maximum power of 1000W at the operating frequency of 385 Hz was selected as the acoustic driver for this project.

(2). Acoustic Resonator

The shape, length, weight and the losses are important parameters for designing the resonator. Length of resonator is determined by the resonance frequency and minimal losses at the wall of the resonator. The length of resonator tube corresponding to half the wave length of the standing wave;

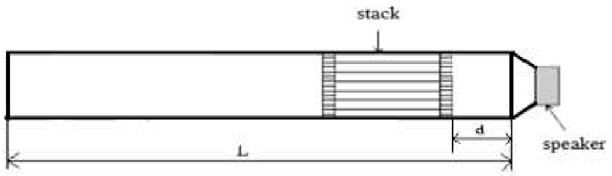
$L = \lambda/2$

And
$\lambda = a/f$
where, a is the speed of sound = 346.5 m/s, λ is the wave length and f is the resonance frequency=385.
$\lambda = 346.5/385 = 0.9m = 900mm$
$Ls = 900/2 = 450$ mm
As discussed earlier an acoustic driver with the resonance frequency of 385 Hz was selected for the present design. For this resonance frequency the length of the resonant tube was equal to 450mm that corresponds to the half wavelength of the acoustic standing wave, the diameter of the resonator tube was set equal to 70mm to accommodate the size of the acoustic driver.

(3). Stack

The most important components of a thermo acoustic device is the stack inside which the thermo acoustic phenomenon occurs. Thus the characteristics of the stack have a significant impact on the performance of the thermo acoustic device. The stack material should have good heat capacity but low thermal conductivity. The low thermal conductivity for the stack material is necessary to obtain high temperature gradient across the stack and heat capacity larger than the heat capacity of air. In addition the stack material should minimize the effects of viscous dissipation of acoustic power.

There are different geometrical configurations of stack such as; parallel plates, circular, hexagonal and square pin arrays. These geometries are used to have efficient thermal contact between the working fluid and the solid surface across the cross sectional area. The pin array and parallel plates stack have shown to be the best geometries. Numerical studies confirm that efficiency and power are almost 10% to 20% more with parallel sided channel than honeycomb channel. The best location to put stack inside the resonator is about λ/20 from the nearest velocity node. In this project, aluminum foil is used as the stack and is placed 45 mm from the speaker end.



$d = \lambda/20 = 900/20 = 45mm$
There are three main stack design parameters which are normalized stack position (Xn), normalized stack length (Ln), and the stack cross sectional area (A). Typically, the resonator tube cross sectional area is equal to the stack cross sectional area. The dimensionless parameters, Xn and Ln are defined as,
$Xn = (2\pi f/a)Xs$
$Ln = (2\pi f/a)Ls$
Where, Ls is the length of the stack and Xs is the distance from the mid length of stack to the nearest end of the resonator tube. Some other normalized parameters used in the design of the stack are;
$\Delta Tmn = \Delta Tm/Tm$
$\Delta kn = \delta k/y0$

Where ΔTm is temperature difference across the two ends of stack, Tm is the mean air temperature inside the resonator tube, ΔTmn is the normalized temperature difference, δk is the thermal penetration depth, and y0 is the half of the spacing length between the stack layers, and δkn is the normalized thermal penetration depth.

The stack is embedded in the resonant tube to acquire the temperature inclination over the stack. In this undertaking, aluminum foil with equal plate geometry was used as the stack. The stack is put in the resonator at distance of 270mm from the speaker and as portrayed before.

(4). Working Fluid

Numerous parameters, for example, power, proficiency and so on are engaged with the choice of the working fluid, and it relies upon the application and target of the device. Thermoacoustic power increments with an expanding the mean pressure inside the resonator. It additionally increments with an expansion in the speed of sound in the working fluid. The lighter gases, for example, H_2, He, Ne have the higher sound speed. Lighter gases are essential for the refrigeration application in light of the fact that heavier gases consolidate or freeze at low temperatures, or display non perfect conduct. Air at barometrical pressure is picked as a working liquid for the current investigation.

4. CONCLUSIONS

Thermo acoustics is a promising area, which if properly explored, could serve as a good refrigeration system. However, the performance of these device is currently very low. The main motivation for the present work was to develop a simple thermo acoustic refrigerator that is completely functional. This project reports on the design and fabrication of a simple thermoacoustic refrigeration system with inexpensive and readily available material.

If we were able to build the device with better materials, such has a more insulating tube, we might have been able to get better results. In order to create a working refrigerator we probably would have to attach a heat sink to the top of the device, thus, allowing the excess heat to dissipate to the surroundings.

ACKNOWLEDGEMENT

I would like to express my sincere gratitude to my guide Prof. Zankar Yadav for the continuous support of my Project study and research, for his patience, motivation, enthusiasm, and immense knowledge. His guidance helped us in all the time of research. I could not have imagined having a better advisor and mentor for my Project study.

REFERENCES

1. W. Swift, “Thermo acoustic engines and refrigeraors,” Phys. Today 48, 22-28 (1995)
2. Tijani, M.E.H., J.C.H. Zeegers, and A.T.A.M. De Waele. "Construction and performance of a thermo acoustic refrigerator." Cryogenics 42 (2001): 59-66.
3. Jin T., Chen G.B., Wang B.R., and Zang S.Y., “Application of thermo acoustic effect to refrigeration.” Review of scientific instruments, 74(1): 677-679, 2003.
4. Jebali F., Lubiez J.V., and Francois M. “Response of a thermo acoustic refrigerator to the variation of the driving frequency and loading” International Journal of Refrigeration, 21(2): 165-175, 2004