Development And Evaluation Of Thermo-Acoustic Refrigeration System

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Abstract - Thermo acoustic refrigeration (TAR) is a phenomenon that uses high intensity sound waves in a pressurized gas tube to pump heat from one place to the other to produce refrigeration effect. This system completely eliminates the need for lubrications and results in 40% less energy consumption.in which compressor replaces with loudspeaker and inert gasses replaces the refrigerant. Experiments were conducted on a reconstructed thermoacoustic refrigerator. The construction utilized the design and various reusable components from a previous major qualifying project.

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. 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.

Thermoacoustic refrigeration summarized

In thermo acoustic refrigeration system the sound is allowed to pass through a resonator tube, this sound wave is sinusoidal in nature and it is of constant frequency. Air or anyother gasses like inert gasses are introduced in the pipe. When the sound wave propogates the compression and rarefaction takes place for every positive and negative half cycle.so in the region of compression we have high temperature and in the region of rarefaction we have low temperature. Thus we can see the temperature difference in system which is the soul purpose of our project. The thermoacoustic effect acts like a conveyor belt for thermal energy. For this to occur, one must exploit two physical principles concerning thermodynamics and acoustics inside the stack. First, through the relation of pressure to temperature by the ideal gas law PV=nRT, the small changes in pressure caused by sound also cause small changes in temperature.

2. Objectives

- To develop environment friendly thermo acoustic refrigeration system.
- To fabricate a working model based on the design using low cost and readily available materials.
- To achieve at least 10 ºC of cooling from thermo acoustic refrigeration system.
- To evaluate the thermo accoustic refrigeration system.
- To better understanding of the fundamental process and necessary to improve the d

3. Materials And Methodology

Working Medium gas

High pressure air can also use as working medium. Thermal penetration depths & the natural frequency of the resonator are also dependent on the choice of working fluid. The helium tank had a pressure gage and the pressures mentioned in the report are in absolute atms based on the readings from this gage which had an uncertainty of .1 atms. Since the refrigerator was not necessarily prepared for a full hard vacuum alternating between vacuum and helium feeds would eventually fill it with helium. For the experiments, the procedure went as follows: 1. Turn on vacuum and leave it for 10 minutes 2. Turn on Helium and leave it for 10 minutes 3. Repeat. Because Helium escapes easily, the helium feed valve and tank were left on throughout the experiment the idea being that any leaks would be forced leaks and would be promptly replaced by more helium.

Speaker

The speaker itself was a 5" diameter Pyle (250X) with a wattage of 200. Instead of a fragile paper speaker panel, it is made of rubber and plastic for more durability, and is thus capable of creating more power amplitudes of sound waves in the apparatus. The speaker was placed into the speaker housing just above a holding so that the He gas could travel beneath and into the resonator/stack

The amplifier itself has a max amplifying capacity of 250 watts, so the speaker itself came within safe boundaries, not overloading the system. The speaker was only about $20 and took 5 days shipping overseas from the manufacturer in china.

Figure speaker

Resonator tube

The resonator is a long copper pipe which connects on one end to the PVC stack housing and has a glass bulb on the other end to simulate and open end. The copper heat exchangers were placed right at the female end of the thin copper tube.

A resonator is necessary to contain the stack and heat exchangers of a Thermoacoustic engine. The resonator should have a high quality factor (Q) to minimize thedissipation of acoustic power into heat. The resonator is designed in order that the length,weight, shape and losses are optimal. The resonator has to be compact, light and strongenough. The shape and length can be determined by the frequency and minimal losses at thewall of the resonator. The cross sectional area (A) of the resonator at the stack location is determined

Figure Resonator tube with buffer volume

Stack

Our construction of the apparatus began by disassembling pieces of the old TAR made by the previous group. We recycled their resonator and stack, but not the stack holding. First, we assembled and sealed the PVC components of the stack holding using PVC cement and caulk. The PVC components had to be drilled through in their insides due to unnecessary rings which blocked the ability for us to put the stack in. Each time we applied caulk or any other sealant or adhesive, we usually waited about 4-6 hours for it to completely dry before moving the pieces around and beginning new tasks. After the stack housing was assembled, the stack fit snugly inside it.

After the stack and copper pipe were assembled, the copper wool was placed inside the resonator tube adjacent to where the stack would connect, and 5 layers of copper mesh were put in to hold the wool and increase the heat exchanging capability. The same process was applied to the copper tube that would connect on the other side of the stack. Teflon tape was then wrapped around the male ends of the PVC stack and then screwed onto the resonator and copper tube.

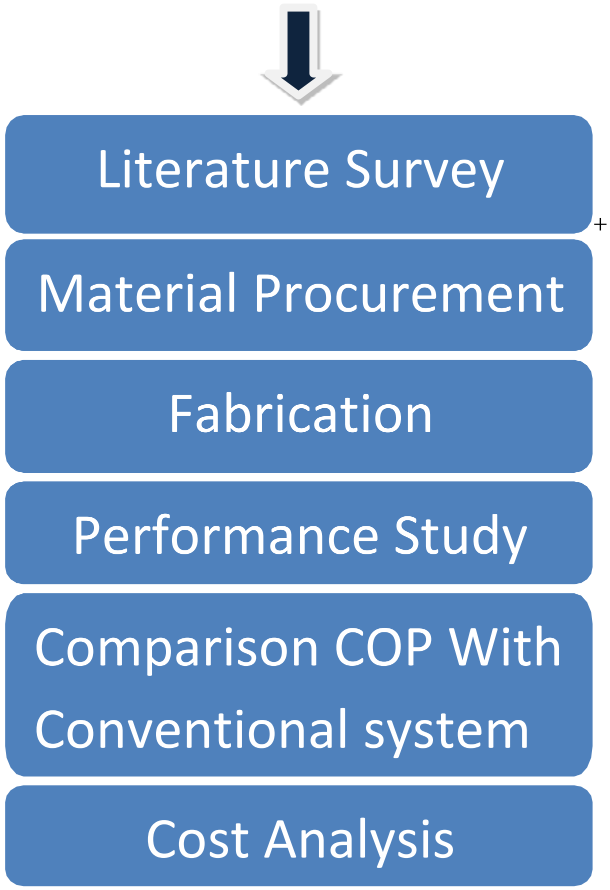
Figure stack housing

Heat Exchanger

Heat exchanger is a component or a device which is use to transfer thermal energy between fluids, it may be two or more than two. There is no external heat or work interaction in heat exchanger. The working of heat exchanger is to remove the heat from high temperature source. In thermo acoustic refrigerator the heat exchanger is used to remove the heat from the stack so that temperature is maintain as per requirement. In thermo acoustic refrigerator two heat exchangers are required one work as hot heat exchanger and other work as cold heat exchanger. The heat exchangers used comprised of two primary components, sections of a copper mesh cut up into 1.5" diameter circles and having 5 placed on either side of the stack. Also, on both the speaker housing and resonator side of the stack.

Figure Heat Exchangers

Methodology



As shown in above figure represents the flowchart of methodology. It represents the steps that will be followed during this project. A thermo acoustic refrigerator functions as follows the procedure.

The next step in the project was to test the constructed apparatus. Because of the problems with helium leaks and other issues, there was no clear distinction between the “construction” and “experimental” stage. As some experiments were being done, the apparatus was modified (i.e. sealing leaks, modifying heat exchangers etc.). There are three subsections in the “Experiments section”. The “Measurements” section details the work done to set up the experiment and the measurement tools (both hardware and software) used. As explained above, the nature of the project was such that experiments were modified

4. Result And Discussion

We analyze the performance of thermo acoustic refrigeration system and we got **The Experimental Values** and temperature difference of **5 ºC** between the two ends of the stack. And where T_C is temperature at cold side end , T_h is temperature at hot side end of resonator tube. ΔT is teperature difference between two ends.

Time (Hour)	Cold side T_C (ºC)	Hot side T_h (ºC)	ΔT
0.00	36.00	36.00	0.0
0.50	35.80	36.50	0.70
1.00	35.00	36.90	1.90
1.50	34.40	37.00	2.40
2.00	33.90	37.10	3.20
2.50	33.00	37.30	4.30
3.00	32.50	37.30	4.80
3.50	32.30	37.50	5.20
4.00	32.20	37.50	5.30

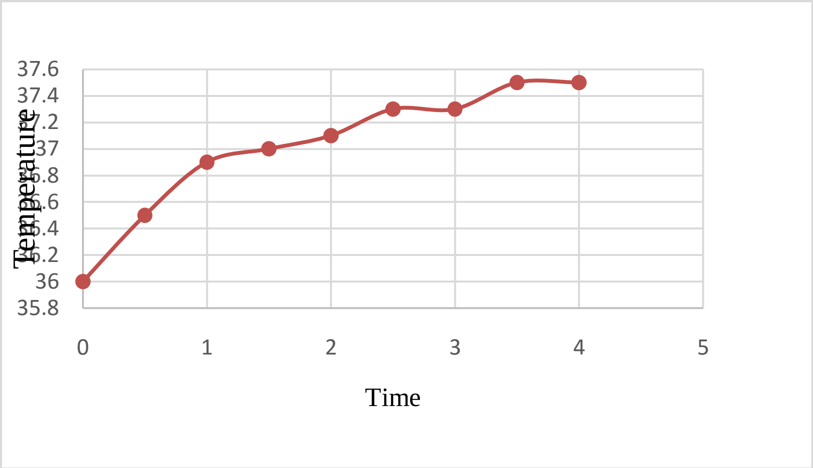


Figure 5.1 Time Vs Temperature Profile

As shown in above fig, at 0 time the temperature at cold side end and hot side end of the stack was 36.0 ºC , after some time period about 4.0 hours then the temperature at cold side end decreases to 32 ºC, there by making temperature difference in system.

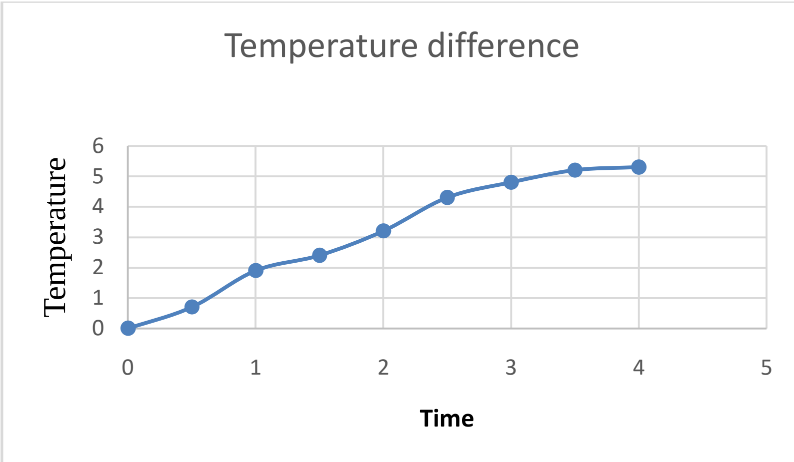


Fig: Temperature difference profile

From above fig, the temperature difference obtained , since the cooling effect has achieved from thermo accoustic refrigeration system.

Conclusion

The goals for this project were to create a better thermoacoustic refrigerator by reconstructing the previous refrigerator and improving measurement techniques. The former was accomplished by putting in a more powerful speaker (our speaker had a power of 200 watts as compared with a speaker with 50 watts with the previous project) and by increasing the pressure of the working fluid, helium, inside the refrigerator. The increase in pressure, however, turned out to be a meaningless step because of the various helium leaks which created a mix of helium and air. The advanced measurement techniques worked well. The thermocouples recorded the temperature of the hot exchanger, cold exchanger, and ambient accurately. The resonance was also measured satisfactorily; but, the process was more tedious than it should have been. A more advanced technique would automatically generate the resonant frequency for any given system.

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