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## A Review on Thermoacoustic Refrigeration

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**ABSTRACT:** Thermo acoustic deals with the conversion of heat energy to sound energy or viceversa. Thermo acoustic cooling devices use the thermo acoustic principle to move heat using sound. They consist of a standing wave tube in which a stack of fractional wavelength creates a temperature gradient across the stack, facilitating heat flow. These devices are simple in design and have no harmful effects on the environment. However, their efficiencies are lower than the conventional vapour-compression refrigeration systems. In this study, the design, and development of a thermo acoustic system for refrigeration application was considered. This study comprised two parts. In the first part, different components of the thermo acoustic refrigerator were designed based on the numerical analysis. In the second parts, the refrigerator was fabricated based on the numerical design. The performance of the device was then tested and analyzed.

The numerical study has shown that the stack length and the position of the stack in the resonator have a significant impact on the overall performance of the thermo acoustic device. Air at standard temperature and pressure is employed as the working gas.

**KEYWORDS:** Vapour compression, numerical analysis

### I. INTRODUCTION

Recent developments in the field of thermo acoustics promise to revolutionize the way that many machines currently operate. By manipulating the temperature-changes along the acoustic longitudinal waves, a machine can be created that can replace current refrigeration and air conditioning devices. These machines can be integrated into refrigerators, home generators, hot water heaters, or space heaters and coolers. The thermo acoustic devices contain no adverse chemicals or environmentally unsafe elements that are characteristics of the current refrigeration systems. 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 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 to absorb heat from a low temperature.

### II. THERMO ACOUSTIC PHENOMENON

Thermoacoustic refrigeration systems operate by using sound waves and a non-flammable mixture of inert gas (helium, argon, air) or a mixture of gases in a resonator to produce cooling. Thermoacoustic devices are typically characterised as either 'standing-wave' or 'travelling-wave'. A schematic diagram of a standing wave device is shown in figure .The main components are a closed cylinder, an acoustic driver, a porous component called a "stack, and two heat-exchanger systems. Application of acoustic waves through a driver such as a loud speaker, makes the gas resonant. As the gas oscillates back and forth, it creates a temperature difference along the length of the stack. This temperature change comes from compression and expansion of the gas by the sound pressure and the rest is a consequence of heat transfer between the gas and the stack. The temperature difference is used to remove heat from the cold side and reject it at the hot side of the system. As the gas oscillates back and forth because of the standing sound wave, it changes in

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temperature. Much of the temperature change comes from compression and expansion of the gas by the sound pressure (as always in a sound wave), and the rest is a consequence of heat transfer between the gas and the stack.

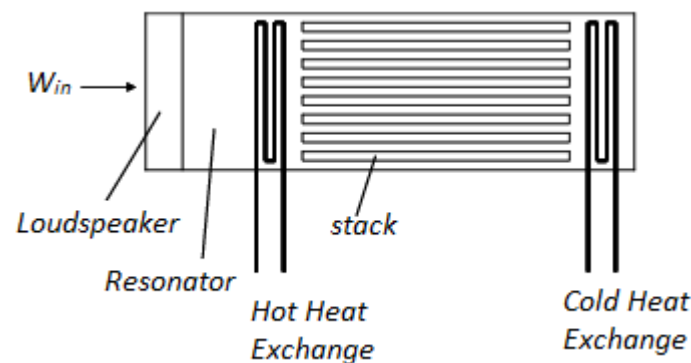


Fig: Sound Wave Thermoacoustic engine

In the travelling-wave device, the pressure is created with a moving piston and the conversion of acoustic power to heat occurs in a regenerator rather than a stack. The regenerator contains a matrix of channels which are much smaller than those in a stack and relies on good thermal contact between the gas and the matrix. The design is such that the gas moves towards the hot heat exchanger when the pressure is high and towards the cold heat exchanger when the pressure is low, transferring heat between the two sides. An example of a travelling wave thermoacoustic device is the Ben & Jerry ice-cream cabinet

### III. LITERATURE REVIEW

During the last two decades thermo acoustic refrigeration is explored as new cooling technology. Thermo acoustic refrigeration are systems which use sound waves to produce cooling power. They consists of a loudspeaker, attached to one end of an acoustic resonator (tube) which is closed at the other end. The loudspeaker sustains and acoustic standing waves in the resonator. A stack of parallel plates and to heat exchanger are appropriately installed in the resonator. The thermal interaction between and the surface of the stack generates a heat pumping process the way these system work is extensively explained in the literature. This paper describe the construction of a thermo acoustic refrigerator. The design procedure of the thermo acoustic refrigerator described elsewhere. The manufacturing process will be explained and the first performance measurements will be presented. This paper starts with a description of the design and construction of the different parts, followed by an explanation of the preparation of the gas mixtures.

### IV. COMPONENT USED IN THERMOACOUSTIC REFRIGERATION

This topic deals with the design, development and optimization of the thermoacoustic refrigerator. Due to the large number of parameters, a choice of some parameters along with a group of dimensionless independent variables will be used. The optimization of the different parts of the refrigerator will be discussed, and likewise some criteria will be implemented to obtain an optimal system.

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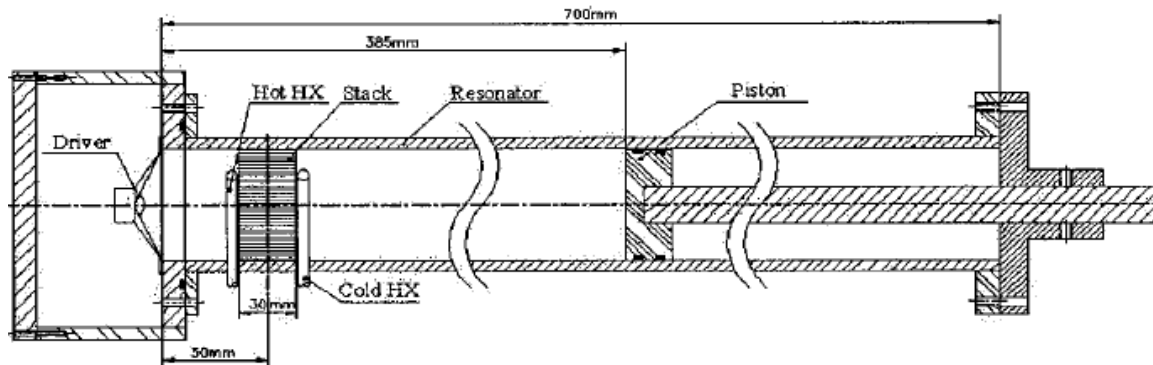


Fig: Thermoacoustic Refrigerator

### 1. Acoustic Driver

A thermo acoustic cooling device requires an acoustic driver attached to one end of the resonator, in order to create an acoustic standing wave in the gas at the fundamental resonant frequency of the resonator. The acoustic driver converts electric power to the acoustic power. In this study, a loudspeaker with the maximum power of 15 watts, and impedance of 8 Ω at the operating frequency (450 Hz) was used as the acoustic driver (G 50 FFL, VISATON). The loudspeaker was driven by a function generator and power amplifier to provide the required power to excite the working fluid inside the resonator. Efficiency of this type of loudspeaker is relatively low, and their impedances are poorly matched to gas when the pressure inside the resonator is high. Consequently the range of pressure amplitude inside the resonator is limited.

### 2. Acoustic Resonator

The acoustic resonator was built from a straight acrylic tube of length 70 cm. The internal diameter of the tube was 6.3 cm and the wall thickness was 6 mm. One end of the tube has a plate attached to install the speaker frame. At the other end, a movable piston was placed inside the resonator. The reason for having a movable piston was to adjust the length of resonator so as to change the fundamental resonant frequency of the resonator. In the present design the resonance frequency of the resonator is 450 Hz. Thus the length of resonator tube was set equal to 38.5cm that correspond to the half wavelength of the acoustic standing wave generated at this frequency. The resonator was sealed at both ends with the rubber O-rings to minimize the sound energy leakage.

### 3. Stack

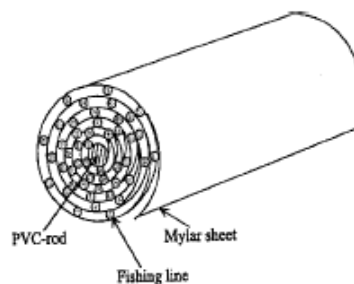


Fig: Spiral Stack

A spiral stack with parallel-plate geometry was used. The stack was made from the Mylar sheet of thickness 0.13 mm. The Mylar sheet was cut into pieces, each 3 cm wide. The spacing between the layers was realized by fishing line

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spacers (0.36 mm thick) glued onto the surface of the sheet. The distance between the two layers, i.e. 0.36 mm, was set larger than the thermal and viscous penetration depths for the design condition. The Mylar sheet was wound around a 4 mm PVC-rod to obtain a spiral stack as shown in Fig.

## 4. Heat Exchanger

The two heat exchangers were built from the 3/16" diameter copper tube. To improve the performance of the heat exchangers, the tubes are bent in the form of "M". The total length of each exchanger is equal to 12 cm. The design of the heat exchangers is critical in thermo acoustics. Since they are placed in front of the stack, they block the motion of the gas particles and hence disturb the thermo acoustic process. Therefore, the heat exchangers have to be designed in a way to minimize the disturbance to the particle motion and to have the effective heat exchange between the stack and the heat exchanger fluids.

## 5. Assembly :

A schematic illustration of the thermo acoustic refrigerator parts is shown in Figure. It consists of an acoustic driver housing, an acoustic driver, two heat exchangers, and stack, a resonator filled with air at atmospheric pressure, position adjustable piston and piston support.

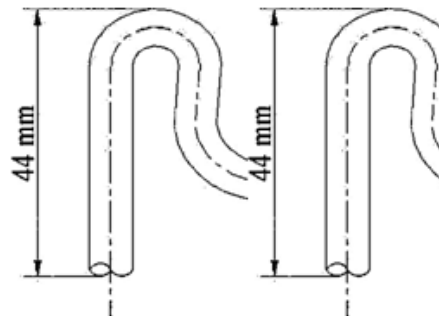


Fig: cold and Hot Heat Exchangers

## 6. Microphone

A condenser microphone cartridge Model 377A10 PCB Piezotronics was used to measure the sound intensity level and dynamic pressure amplitude inside the resonator when the loudspeaker was excited. The microphone consists of a microphone cartridge and a microphone preamplifier. A preamplifier Model 426B03 was used in order to measure the sound intensity. The cartridge screws directly onto the preamplifier housing. Frequency responses are almost flat between 5Hz and 100 kHz (see Appendix A and B for the detailed specifications). In this case microphone and piston are always at the same position i.e. at the pressure antinodes, and it can always measure the maximum pressure.

## 7.Sensor:

One microphone and ten thermocouples were used in the experiments to measure the sound intensity and temperature, respectively.

## 8.Thermocouple:

T-type thermocouples were used for the temperature measurements in this study. They were used to measure the temperature at different locations inside the resonator and the temperature of heat exchanger fluids. The specifications of the thermocouple are given below:

- Thermocouple Grade:-200 to 350 °C
- Limits of Error: 1.0 °C or 0.75% above 0 °C

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The output of the thermocouple is very low (0.263 mill volts). A signal conditioner (SCXI-1102, National Instruments) was used to amplify and increase the signal-to-noise ratio of the original signal. The accuracy of the temperature measurement is 1 °C.

## 9. Electronic Devices:

A Function generator model Agilent 33120A was used that could generate sine waves with different frequencies or sweep the frequency from 10 Hz to 2500 Hz, to drive the loudspeaker. An amplifier (MPA-25, Realistic) with the maximum power output of 20 watts was used to amplify the power input to the loudspeaker to increase power input. In order to acquire, process and analyze the microphone signal data, a signal analysis unit type 2035 Bruel & Kjaer and an amplifier (PCB 482A06, Piezotronics) were used.

## 10. Electronic Metering Pump:

The EZ series electronic metering pump model EZB10N1-VE was used to pump water through the cold and hot heat exchangers. It consists of a pump unit, a drive unit, and a control unit. The drive unit is electromagnetic solenoid type.

## 11. Data Acquisition:

A 16 channel data acquisition card (PCI-6036E, National Instruments) was used for the data acquisition. The card was installed in the PC. Lab View software was used for the data acquisition. The temperature data from all thermocouples and the sound signal from the microphone were acquired simultaneously.

## 12. Measurement procedure:

These types of experiments were conducted:

- Measurements inside the resonator without the stack and heat exchangers.
- Measurements inside the resonator with the stack but without the heat exchangers.
- Measurements inside the resonator with the stack and heat exchangers

In this chapter, the development of the actual components of the thermo acoustic refrigerator based on the design presented in the previous chapter, are discussed. Also, the experimental setup and experiments were described and the methods for acquiring the data and measurement were explained. The experimental results will be present in the next chapter. In this chapter, the development of the actual components of the thermo acoustic refrigerator based on the design presented in the previous chapter, are discussed. Also, the experimental setup and experiments were described and the methods for acquiring the data and in this chapter, the development of the actual components of the thermo acoustic refrigerator based on the design presented in the previous chapter, are discussed. Also, the experimental setup and experiments were described and the methods for acquiring the data and measurement were explained. The experimental results will be present in the next chapter

## V. CONCLUSION

Thermo acoustics is a promising area, which if properly explored, could serve as a renewable energy source. In a complete thermo acoustic system, the heat is used in the prime mover to generate acoustic wave. This acoustic wave is then used as an input to the thermo acoustic refrigerator. Thus, a thermo acoustic system could use waste heat and drive a refrigerator. However, the efficiency of these devices is currently very low and thus, cannot compete with their conventional counterparts. The main motivation for the present work was to develop a simple thermo acoustic refrigerator that is completely functional. This thesis reports on the design and development of a simple, low-power thermo acoustic system for the refrigeration application. The design and development comprised of two parts. In the first part, different components of the refrigerator were designed based on the given operating conditions from the theoretical analysis. The results have shown that the performance of the refrigerator depends on the working gas, pressure inside the resonator tube, shape of resonator tube, material, position and length of the stack. The performance of the stack was also simulated numerically.

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