ISSN XXXX XXXX © 2019 IJESC

Research Article Volume 9 Issue No.3

Refrigeration using Sound Energy (Thermoacoustic Refrigeration)

K. Murali[1], V. Manikandan[2], E. Rajadurai[3], K. Rajkumar[4], P. Logeshwaran[5]
Research Scholar[1], BE Student[2, 3, 4, 5]
Department of Mechanical
Anna University, Arni Campus, Arni, India

Abstract:
Thermo acoustic refrigeration is a new alternative for cooling that is eco-friendly and inexpensive. The construction of a functional model will demonstrate the effectiveness of the new idea for modern cooling. Refrigeration cycle relies on two major thermodynamic principles. First, a fluid's temperature will rise when compressed and will fall when expanded. Second, when two substances are placed in direct contact of each other, heat will flow from the hotter body to the cooler body. While traditional refrigerators use pumps to transfer heat on a large scale, Thermo acoustic refrigerators depend on sound waves to generate waves of pressure that will alternately expand and compress the gas particles within the tube. The model constructed for this research project employed is inexpensive, household materials. For commercial use there is way more to research and develop in this technology.

Keywords: Aluminum Body, Copper type heat exchanger No. of tubes increases, Nylon stack, Acoustic Refrigeration, Fouling

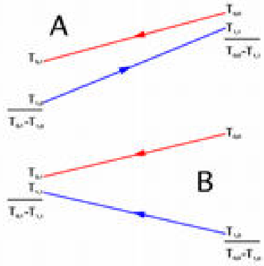
I. INTRODUCTION

In 19th century, modern refrigeration technologies were introduced to world. In the last few decades the use of them has increased significantly. Today mostly cooling is achieved by vapor compressor system that use a specific refrigerant. In recent years, it has been discovered that traditional refrigerators affect the environment adversely. So to avoid the use of hazardous materials the idea of Thermo acoustic refrigerators was developed. 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 inter conversion 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. In Los Alamos National Laboratories (LANL), a team consisting of Gregory W Swift, J. C. Wheatley and Thomas J. Hofler accidently developed the first modern TAR when they tried to power a heat pump with the help of a Stirling engine. thermo acoustic Refrigeration System mainly consist of a loudspeaker attached to an acoustic resonator (tube) filled with a gas. In the resonator, a stack consisting of a number of parallel plates and two heat exchangers are installed. The loudspeaker, which acts as the driver, sustains acoustic standing waves in the gas at the fundamental resonance frequency of the resonator. The acoustic standing wave displaces the gas in the channels of the stack while compressing and expanding respectively leading to heating and cooling of the gas. The gas, which is cooled due to expansion absorbs heat from the cold side of the stack and as it subsequently heats up due to compression while moving to the hot side, rejects the heat to the stack. Thus the thermal interaction between the oscillating gas and the surface of the stack generates an acoustic heat pumping action from the cold side to the hot side. The heat exchangers exchange heat with the surroundings, at the cold and hot sides of the stack. The heat exchangers are used so that heat interaction with the surrounding takes place. Heat is pumped from the cold end heat exchanger to the hot end heat exchanger. Fig. 1 shows the pressure variation and displacement of sound waves in thermo acoustic refrigeration system. It is known that sound waves are longitudinal waves. They produce compression and rarefaction in the medium they travel. Maximum pressure occurs at the point of zero velocity and minimum pressure at maximum velocity.

II. Comparison of Thermoacoustic Refrigeration System With Other Refrigeration Systems

Apart from vapour compression devices, there are several other ways to provide cooling and refrigeration. Although none of these are currently as versatile as a Vapour Compression Systems but some of these systems hold a high possibility of replacing the pollution causing Vapour Compression Systems. Comparison with various systems is as follows. A. Type of Refrigerant the Absorption Refrigeration uses a binary mixture of refrigerant and absorbent like Water/ammonia or LiBr/water. The Adsorption system uses natural refrigerants like water, ammonia or alcohol. Thermo-electric and Thermoacoustic Refrigeration Systems do not use any refrigerant. B. Working Cycle Vapour Absorption Refrigeration is a two stage process. The vapour refrigerant is absorbed in a binary solution which then regenerates the refrigerant on heating externally. It is cooled in the condenser to the required pressure level and the cycle repeats. Much like the Vapour Compression Refrigeration Systems the Adsorption Systems are also based on withdrawing heat from surroundings during an evaporation process. Thermo-electric System is based on the Peltier Effect wherein an electric current passing through a junction of two materials will cause a change in temperature. The Thermoacoustic Refrigeration System is powered by either a heat engine running on waste heat or an electric source. A heat exchanger is a device used to transfer heat between two or more fluids. In other words, heat exchangers are used in both cooling and heating processes. The fluids may be separated by a solid wall to prevent mixing or they may be in direct contact. They are widely used in space heating, refrigeration, air conditioning, power stations, chemical plants, petrochemical plants, petroleum refineries, natural-gas processing, and sewage treatment. The classic example of a heat exchanger is found in an internal combustion engine in which a circulating fluid known as engine coolant flows through radiator coils and air flows past the coils, which cools the coolant and heats the incoming air. Another example is the heat sink, which is a passive heat exchanger that transfers the heat generated by an electronic or a mechanical device to a fluid medium, often air or a liquid coolant.

A. *Flow arrangement*



Countercurrent (A) and parallel (B) flows

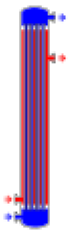


Figure.1. Shell and tube heat exchanger, single pass (1–1 parallel flow)

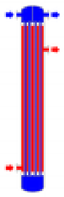
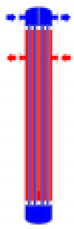


Figure.2. Shell and tube heat exchanger, 2-pass tube side (1–2 crossflow)



There are three primary classifications of heat exchangers according to their flow arrangement. In *parallel-flow* heat exchangers, the two fluids enter the exchanger at the same end, and travel in parallel to one another to the other side. In *counter-flow* heat exchangers the fluids enter the exchanger from opposite ends. The counter current design is the most efficient, in that it can transfer the most heat from the heat (transfer) medium per unit mass due to the fact that the average temperature difference along any unit length is *higher*. See countercurrent exchange. In a *cross-flow* heat exchanger, the fluids travel roughly perpendicular to one another through the exchanger. For efficiency, heat exchangers are designed to maximize the surface area of the wall between the two fluids, while minimizing resistance to fluid flow through the exchanger. The exchanger's performance can also be affected by the addition of fins or corrugations in one or both directions, which increase surface area and may channel fluid flow or induce turbulence. The driving temperature across the heat transfer surface varies with position, but an appropriate mean temperature can be defined. In most simple systems this is the "log mean temperature difference" (LMTD). Sometimes direct knowledge of the LMTD is not available and the NTU method is used.

III. SPECIFICATIONS FOR THERMOACOUTIC REFRIGERATION

- Speed of sound in gas - 1013 m/s
- Gas specific heat - 5193 J/kgK
- Gas specific diffusivity – $13.2*10^{-5}$ m^2/s
- Gas specific conductivity – 0.155 W/mK
- Gas dynamic viscosity – $197*10^{-7}$ Ns/m^2
- Gas density – 0.8845 Kg/m^3
- Drive ratio – 0.02
- Ratio of specific heats – 1.67
- Normalized stack length – 0.262
- Blockage ratio – 0.5

IV. TRANSFORMATION OF HEAT ENERGY INTO INTENSE

As shown in Fig. 1.1, Thermo acoustic device consists, in essence, of a gas-filled tube containing a ―stack‖ (top), a porous solid with many open channels through which the gas can pass. Resonating sound waves (created, for example, by a loudspeaker) forcegas to move back and forth through openings in the stack. If the temperature gradient along the stack is modest (middle), gas shifted to one side (a) will be compressed and warmed so that a parcel of gas with dimensions that are roughly equal to the thermal penetration depth (dk) releases heat to the stack. When this same gas then shifts in the other direction (b), it expands and cools enough to absorb heat. Although an individual parcel carries heat just a small distance, the many parcels making up the gas form a ―bucket brigade,‖ which transfers heat from a cold region to a warm one and thus provides refrigeration. The same device can be turned into a thermo acoustic engine (bottom) if the temperature difference along the stack is made sufficiently large. In that case, sound can also compress and warm a parcel of gas (c), but it remains cooler than the stack and thus absorbs heat. When this gas shifts to the other side and expands (d), it cools but stays hotter than the stack and thus releases heat. Hence, the parcel thermally expands at high pressure and contracts at low pressure, which amplifies the pressure oscillations of the reverberating sound waves, transforming heat energy into acoustic energy.

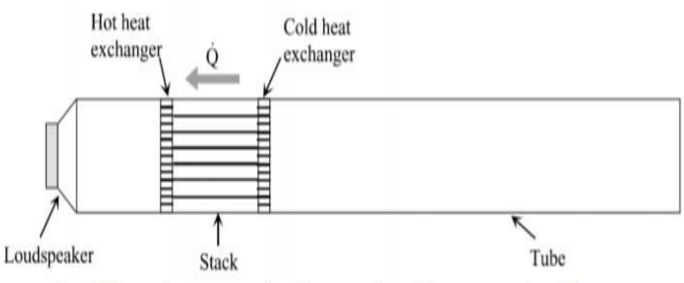
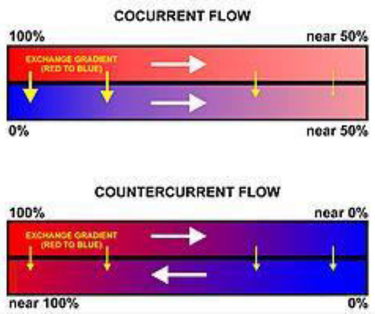


Fig. 1 Schematic representation of construction of thermoacoustic refrigerator.

Flow arrangements



A comparison between the operations and effects of a cocurrent and a countercurrent flow exchange system is depicted by the upper and lower diagrams respectively. In both it is assumed (and indicated) that red has a higher value (e.g. of temperature) than blue and that the property being transported in the channels therefore flows from red to blue. Note that channels are contiguous if effective exchange is to occur (i.e. there can be no gap between the channels).

There are three main types of flows in a spiral heat exchanger:

• Counter-current Flow: Fluids flow in opposite directions. These are used for liquid-liquid, condensing and gas cooling applications. Units are usually mounted vertically when condensing vapour and mounted horizontally when handling high concentrations of solids.
• Spiral Flow/Cross Flow: One fluid is in spiral flow and the other in a cross flow. Spiral flow passages are welded at each side for this type of spiral heat exchanger. This type of flow is suitable for handling low density gas, which passes through the cross flow, avoiding pressure loss. It can be used for liquid-liquid applications if one liquid has a considerably greater flow rate than the other.
• Distributed Vapour/Spiral flow: This design is that of a condenser, and is usually mounted vertically. It is designed to cater for the sub-cooling of both condensate and non-condensables. The coolant moves in a spiral and leaves via the top. Hot gases that enter leave as condensate via the bottom outlet.

V. CONCLUSION

Thermoacoustics is a relatively new field of physics that combines acoustics, thermo-dynamics and fluid dynamics to describe the interplay between heat and sound. Since the late sixties, research in this area has yielded devices capable of converting part of the heat flowing through a temperature gradient into large amplitude sound waves and vice-versa with efficiencies now close to those of established technologies. In recent years, thermoacoustic engines, heat pumps and refrigerators have been gaining a lot of attention due to their inherent mechanical simplicity and to their use of environmentally friendly working gases. One of the most promising areas of application for these devices seems to be the use of low temperature industrial waste heat. This thesis focused on the design and assembly of a low cost traveling wave thermoacoustic engine prototype intended to be used for low temperature waste heat recovery. This prototype will allow measuring how different parameters affect the performance of a low cost engine, in search for an optimal configuration. At temperature differences below the onset temperature, the incident sound wave is partially reflected upon encountering the ceramic stack, while being partially transmitted. Pressure measurements from microphone B show that as the temperature difference across the stack increases, the pressure is decreasing. Because this recorded pressure is a superposition of the incident and reflected wave, the reflected pressure must be decreasing as the temperature difference increases. Therefore, as the temperature difference increases, the reflection coefficient is decreasing, and one can assume that the resistance in the system is decreasing. The work in Synchronization Characteristics of Thermoacoustic Laser was to study the interaction between the sound waves, generated from the two thermoacoustic lasers which were coupled acoustically.Sound pressure levels were measured in three different orientations from the open end of the tube, inorder to study the nature of the spherical sound waves exiting the laser tube. For all the orientations, there was a slight variance in pressure levels in the close vicinity of the openend of the laser tube, whereas at distances greater than 10 cm away from the open end, the pressure levels were approximately equal.

VI. REFERENCES

[1]. Sophie Collard, Design & Assembly of Thermoacoustic Engine Prototype, Helsinki Metropolia University of Applied Sciences, Aug.2012.

[2]. Andrew C. Trappy, Florian Zinkz, Oleg A. Prokopyevx, Laura Schaefer, Thermoacoustic Heat Engine Modeling and Design Optimization, July 27, 2011.

[3]. Holly Ann Smith, Impedance Measurement of a Thermoacoustic Engine Constructed from a Helmholtz Resonator, In Partial Fulfillment of Departmental Honors Requirements, University of Central Arkansas Conway, Arkansas 7203 Spring 2008 Thermoacoustic Effect: the Power of Conversion of Sound Energy & Heat Energy: Review (IJRTS/Vol. 1/Issue 4/March 2014) Copyright©IJRTS | www.ijrts.com 28

[4]. Chris van Dijk TUDelft, Thermoacoustic multistage configuration analysis, Master Thesis, 2010.

[5]. Dissertation advisor:Dr. Jaikrishnan R. Kadambi, A THERMOACOUSTIC ENGINE REFRIGERATOR SYSTEM FOR SPACE EXPLORATION MISSION by SUDEEP SASTRY Submitted in partial fulfillment of requirements for the degree of Doctor of Philosophy, Department of Mechanical and Aerospace Engineering, CASE WESTERN RESERVE UNIVERSITY, May 2011.

[6]. Kees de Blok, MULTI-STAGE TRAVELING WAVE THERMOACOUSTICS IN PRACTICE, 19th International Congress on Sound and Vibration, Vilnius, Lithuania, July 8-12, 2012.

[7]. Dilip R. Ballal.,Thermoacoustic Modeling of a Ga Turbine Using Transfer Functio Measured Under Full Engine Pressure, Contributed by the International Gas Turbine Institute (IGTI) of ASME for publicationin The JOURNAL OF ENGINEERING FOR GAS TURBINES AND POWER. Manuscriptreceived May 6, 2009; final manuscript received May 7, 2009; published onlineAugust 10,

[8]. Investigation of thermoacoustic processes in a travelling-wave looped-tube thermoacoustic engine, A thesis submitted to The University of Manchester for the degree of Doctor of Philosophy in the Faculty of Engineering and Physical

Sciences, 2012, Abdulrahman Sayed Ahmed Abduljalil School of Mechanical, Aerospace and Civil Engineering.

[9]. Kees de Blok, NOVEL 4-STAGE TRAVELING WAVE THERMOACOUSTIC POWER GENERATOR, Aster Thermoakoestische Systemen Smeestraat 11, 8194LG Veesse The Netherland, August 2-4, 2010, Montreal, Canada.

[10]. WU ZhangHua1, MAN Man1, 2, LUO ErCang1*, DAI Wei1 & ZHOU Yuan1,Experimentalinvestigation of a 500 W traveling-wave thermoacoustic electricity Generator 1Key Laboratory of Cryogenics, Chinese Academy of Sciences, Beijing 100190, China; 2Graduate University of Chinese Academy of Sciences, Beijing 100049, China Received January 21, 2011; Accepted April 6, 2011.

[11]. A Study on the Synchronization Characteristics of Thermoacoustic Laser, Sung Seek Park, Seung Jin Oh,Won Gee Chun, Kuan Chen, and Nam Jin Kim, Journal of Clean Energy Technologies, Vol. 1, No. 2, April 2010.