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# To Study and Analyse the Performance of A Standing Wave Thermoacoustic Refrigerator- A Review

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**Abstract:** Since the late 20th century, everyone is dealing with deteriorating environmental conditions, i.e. global warming and ozone depletion due to various FCs, CFCs, HCFCs and HFCs. To remove such tyrannical aspects of environmental eradication, thermoacoustic refrigeration concepts should be involved. Thermoacoustic refrigeration system may prove very useful if further exploration and analysis have done because it is harmless type of refrigeration system. Thermoacoustic Refrigerators works on the pressure waves developed due to sound and provide the cooling effect. Establishment of refrigerators based on thermoacoustic technology is an innovative solution to the contemporary and upcoming day need of cooling system, without jeopardising environment and ecosystem.

**Keywords:** Fin Spacing, Fin Geometries, Temperature Distribution, Height, Length, Heat Transfer Rate, Refrigeration Effect, Penetration Depths, Performance Optimisation, Environment Favourable.

## I. INTRODUCTION

Thermoacoustics is the combination of acoustics and thermodynamics taken together to transfer or carry heat by using sound wave. Acoustics is primarily involved with the macroscopic effects of pressure waves transfer, like coupled pressure and motion oscillations. Thermoacoustics deals with the microscopic temperature oscillations that co-exists with these pressure variations. Thermoacoustics takes advantage of these pressure oscillations to move heat on a macroscopic level resulting in a large temperature gradient between both heat exchangers of the stack.

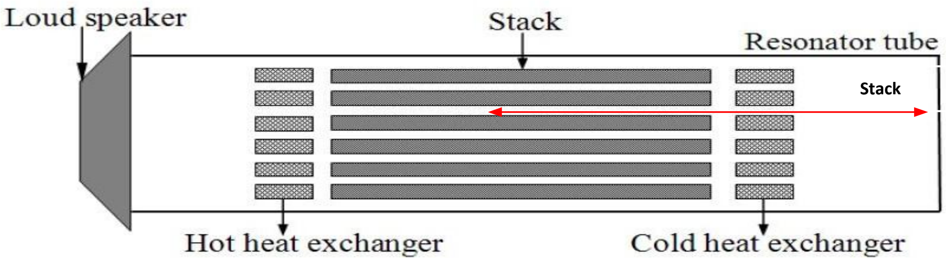


Figure1: Schematic diagram of a typical Thermoacoustic refrigerator

Thermoacoustic refrigerators (Figure 1) consist primarily of a speaker (a vibrating diaphragm or thermoacoustic prime mover) attached to a resonator filled with gas, a stack usually made of thin parallel plates, and two heat exchangers placed at either side of the stack. The stack forms the heart of the refrigerator where the heat-pumping process takes place, and it is thus a critical element for determining the performance of the refrigerator (Swift, 1988). For the temperature gradient along the stack walls to remain steady, the material selected should have higher heat capacity and lower thermal conductivity than the gas; otherwise the stack won't be affected by the temperature oscillations of the nearby gas. In addition, a material of low thermal conductivity must be used for the stack and the resonator to prevent leaking from the hot side of the resonator back to the cold side and to withstand higher pressure

The pressure and displacement oscillations in a sound wave are accompanied by temperature oscillations. For an adiabatic sound wave propagating through an ideal gas, the, temperature oscillations, $T_1$ are related to the pressure oscillations $P_1$, as:

$$T_1/T_m = (P_1/P_m)^{\gamma-1/\gamma} \quad (1.1)$$

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Where $T_m$ and $P_m$ are mean temperature and mean pressure respectively while $T_1$ and $P_1$ are working temperature and pressure respectively.

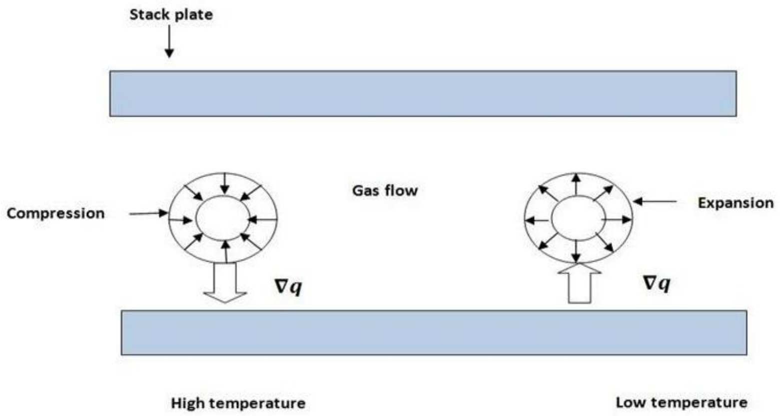


Figure 2: Thermoacoustic processes in one cycle of operation.

**Advantages & Disadvantages of TAR**

The main advantage of thermoacoustic refrigeration system is that it does not release any harmful element that can be proved dangerous to the environment or living beings. It also can work on low grade energy (i.e. heat) and this system is known as Thermoacoustically driven TAR. It is simple to construct and can easily be carried. It does not employ any rotating or reciprocating component. The power supplied for working of TAR is very less when compared to other refrigeration systems.

Apart from advantages, this system too have some disadvantages like it should be hermitically or adiabatically sealed as the working substance is a gas. Also, the COP of TAR is comparatively less than the Vapour compression and absorption cycles.

**Application**

TAR can be used for cooling of those components where fins cannot be employed, i.e. for cooling of small electronic circuits and chips. It can also be used for the refrigeration purposes on naval ships and space crafts. A better model can also be used to convert industrial waste sound and heat energy to provide cooling effect.

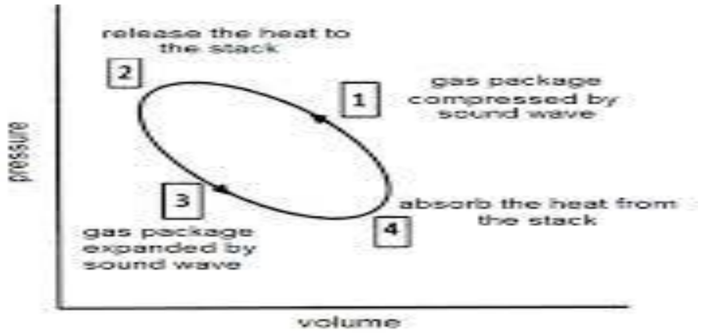


Figure 3: Thermodynamic working cycle of TAR

## II. LITERATURE REVIEW

Thermoacoustics, in its most general sense, is the study of the interaction between heat and sound. The term has of late become restricted in its meaning so that it covers mainly to the field which interacts to heat engines and refrigerators. The project objective is to design and develop a prototype using thermoacoustic refrigeration that will leave a smaller footprint on the environment than current conventional refrigeration. Obstacles faced will include; finding the correct wavelength and frequency,thermal and viscous penetration depth, portability, profitability, and finally ease to manufacture.

The two well-known thermoacoustic effects- thermoacoustic pressure wave generation and thermoacoustic heat pumping are very well explained by the classical Linear Theory of Thermoacoustics. The Linear Theory has also been successfully implemented in development of practical prime movers and refrigerators.

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After successful flourishing TAR developed by Hofler in 1986 which had a capacity of 6-Watts, Thermoacoustic refrigeration becomes an emerging cooling technology against the conventional VCRS system without any adversarial effect on the environment However the TAR demanding the effective tuning between sound waves and resonator tube frequency, efforts are made in a diverse course to overwhelmed these issues.

**Putnam and Dennis et.al[1]** research in thermoacoustics started as early as 1777, when Byron Higgins positioned a hydrogen flame in a massive pipe open at each ends, producing sound. Higgins mentioned that the acoustic oscillations produce by using the tube depended upon the function of the flame.

**Rijke et.al[2]** investigated acoustic oscillations in a comparable equipment however with the hydrogen flame changed via a mesh of heated metallic wire. He determined that sound was once solely produced whilst the tube was once in a vertical orientation and the heating factor was once in the decrease 1/2 of the tube, indicating that the convective drift created by way of heating air in the pipe used to be necessary to its sound production.

**N Yassen et.al [3]** presumed that the sound created was most intense when the work warmer was a fourth of the cylinder length from the base. These investigations subsequently led to pulse combustion technology, which is solely particularly associated to the thermoacoustic gadget designed in this thesis.

**MEH Tijani et.al[4]** fabricated a thermoacoustic cooler with working fluid as helium, kept the geometry of stack as parallel type and fitted two heat exchangers at both ends of parallel plate stack (called them hot and cold heat exchanger with parallel stack geometry) in resonator tube. For fine-tuning between the loudspeaker frequency and frequency of resonator tube an additional mechanism introduced, an experiment performed with two different structure of stack (parallel and spiral).

**L K Tarbitu [5]** worked on various stack geometries of TAR. He proposed a honeycomb structure of stack for heat carrier. He used air as a working fluid inside the resonator and achieved maximum COP when stack is kept near pressure antinode.

**Bisio and Rubato et.al [6]** experimented with a closed-open tube heating it by using making use of a flame to the bulb at the closed cease to produce sound. Sondhauss[7] explored the connection between the geometry of the resonating tube and the frequency of the sound produced. He seen that the oscillation frequency was once linked to the size of the tube and the extent of the closed cease bulb. Furthermore, Sondhauss discovered that the sound used to be extra excessive when a hotter flame used to be applied. However, Sondhauss did now not provide an rationalization of the observations. An assessment of Sondhauss work has been written by way of Feldman

**J. Xu et.al [8]** has presented theoretical model with numerical simulation for variation in pressure, temperature, Reynolds number and velocity of sound in working gas. The change of temperature in cold and hot heat exchangers with respect to time were recorded and discussed. Initially, a temperature drop was very small but with time, variation a maximum temperature has reached on warmth region across the stack and minimum temperature in the cold region of the stack, at these condition temperature gradients was sufficient to produce the higher cooling effect with lower losses.

**G.Allesina et.al [9]** designed and built a standing waves refrigerator with more attention on woofer box containing loudspeaker, insulation around the stack to reduce the losses . A Woofer box critically designed to reduce the sound emission behind the loudspeaker; a mechanism identical to gas spring system developed to push the gas from backside of a sound generator to front side, with a critically designed component of the system a temperature variation of 24ºC had achieved. The disturbance of sound waves was common when resonator tube becomes narrow.

**Taconis et.al [10]** In working with liquid helium, a massive temperature gradient used to be imposed on a glass tube. The temperature gradient, spanning from room temperature to cryogenic temperatures (~2K), prompted spontaneous oscillations interior the glass tube. These oscillations had been later studied by means of Yazaki et al. [11]. Although Taconis furnished an rationalization of the oscillations, his qualitative principle was once essentially the equal as that which had already been proposed by way of Lord Rayleigh many years previously to account for observations of the Sondhauss tube.

**Kirchoff et.al [12]** commenced quantitative principle of thermoacoustics in 1878. He derived equations that accounted for thermal attenuation of sound as nicely as the everyday viscous effects. Kirchhoff then utilized his effects to the case of a tube with a giant radius so that the viscous and thermal results due to the strong boundary ought to solely be viewed in a skinny movie of the fluid shut to the wall. Slightly extending this work, Rayleigh went on to think about slim channels, however the principle was once nevertheless solely in the context of sound.

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**Krammer et.al [13]** In 1949, motivated by Taconis, derived a linear theory of thermoacoustics in an attempt to explain the behaviour of sound in a tube with a temperature gradient; however, the resulting calculations were not in good agreement with experimental results, differing by orders of magnitude. Some of Kramers' early simplifying assumptions were found to be invalid.

**Rott et.al [14]** In 1969a major breakthrough came with Rott's investigation of thermoacoustics. Like, Kramers[13], Rott was primarily concerned with explaining Taconis oscillations, but Rott's efforts proved more fruitful. Publishing many papers on the subject, Rott developed a successful general linear theory of thermoacoustics. With this theory, thermoacoustic devices including both refrigerators and engines could be designed and investigated.

**E.C.Nsofor et.al.[15]** examine the effect of operating pressure and frequency on the performance of TAR, to reduce the axial heat conduction within stack a whole resonator made by aluminum tube covered with the plastic tube. The authors had discussed the effect of a temperature gradient within the stack, with an increase in temperature gradient the cooling load increases. The main intention of this study is to optimize the operating frequency and pressure which result in higher cooling load and improved system performance. There was a certain operating range within which increase in operating pressure result in higher performance beyond this range, an adverse effect on system performance inveterate experimentally.

## III. CONCLUSION

It can be summarised by the literature that the theory of standing wave thermoacoustics is well established. Several theoretical fashions as nicely as simulation software program to forecast the overall performance of TAR at consistent kingdom is additionally available.it is determined to sketch and strengthen a standing wave thermoacoustic fridge successful of cooling to temperatures close to 250 K. Due to time restricted layout statistics on acoustic drivers, a commercially accessible electro-dynamic motor will be used. All different elements of the fridge would have designed to adapt to the reachable motor. The impact of working parameters on TAR overall performance at constant as nicely as transient nation would have investigated theoretically and experimentally.

Thermal penetration depth and position of stack towards the acoustic driver is the main concern we have to take care of. Viscous penetration depth is inevitable and cannot be changed much as our accordance and hence it is considered to be an independent variable. Working gas should be the mixture of helium and any other noble gas and the sheet used should be the mylar sheet.

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