"Feasibility study of Thermoacoustic Cooling in mobile phones"

Dr Suwarna Torgal

Assistant Professor, Department of Mechanical Engineering' IET, DAVV, Indore, India

ABSTRACT

Thermoacoustic refrigeration is an innovative method for cooling devices such as mobile phones as new generation mobiles are embedded with multi-function, gaming, higher power applications associated with the internet which ensure consumption of more energy and higher heat dissipation. Heat dissipation despite of natural phenomenon can affect the performance of such device as the current cooling methods of natural convection and radiation limit the heat dissipation within a mobile phone up to 6 W varying from one to other. So as to ensure their composure and smooth functioning, synchronous cooling methodologies are required other than classical one. Concerning above author suggested acoustic cooling in mobile phones as an alternative cooling technique .The ultimate perspective of the author is to propose the feasibility of acoustic cooling in such devices.

Keyword, *Thermoacoustic cooling, Mobile phones*

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1 .Introduction

Refrigeration relies on two major thermodynamic principles. First, a fluid's temperature rises when compressed and falls when expanded. Second, when two substances are placed in direct contact, heat will flow from the hotter substance to the cooler one. While conventional refrigerators use pumps to transfer heat on a macroscopic scale, thermoacoustic refrigerators rely on sound to generate waves of pressure that alternately compress and relax the gas particles within the tube.Thermoacoustics is based on the principle that sound waves are pressure waves. These sound waves propagate through the air via molecular collisions. The molecular collisions cause a disturbance in the air, which in turn creates constructive and destructive interference. The constructive interference makes the molecules compress, and the destructive interference makes the molecules expand. One method to control these pressure disturbances is with standing waves. Standing waves are natural phenomena exhibited by any wave, such as light, sound, or water waves. In a closed tube, columns of air demonstrate these patterns as sound waves reflect back on themselves after colliding with the end of the tube. When the incident and reflected waves overlap, they interfere constructively, producing a single waveform. This wave appears to cause the medium to vibrate in isolated sections as the travelling waves are masked by the interference. Therefore, these "standing waves" seem to vibrate in constant position and orientation around stationary nodes. These nodes are located where the two component sound waves interfere to create areas of zero net displacement. The areas of maximum displacement are located halfway between two nodes and are called antinodes. The maximum compression of the air also occurs at the antinodes. Due to these node and antinode properties, standing waves are useful because only a small input of power is needed to create a large amplitude wave. This large amplitude wave then has enough energy to cause visible thermoacoustic effects. All sound waves oscillate a specific amount of times per second, called the wave's frequency, and is measured in Hertz. For our thermoacoustic model we had to calculate the optimal resonant frequency in order to get the maximum heat transfer rate. The equation for the frequency of a wave traveling through a closed tube is given by:

$$f = v/4L \qquad (1)$$

Where f is frequency, v is velocity of the wave, and L is the length of the tube.

F

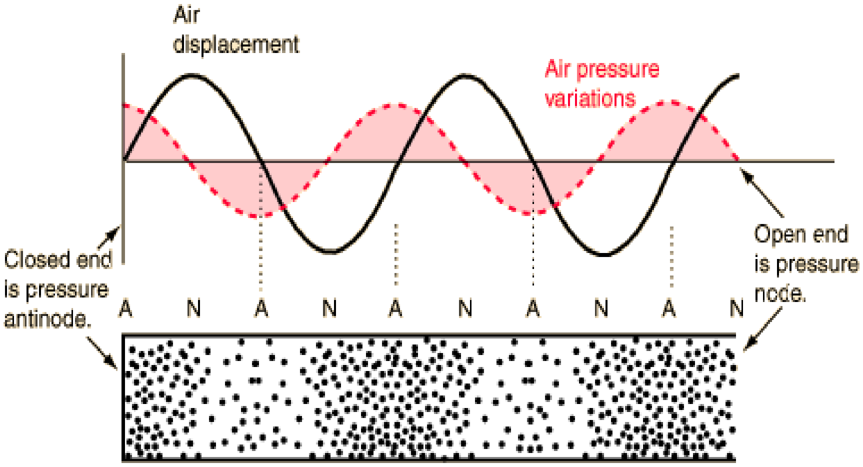

Figure 1:

Shows the relationship between the phase of the wave, the pressure, and the actual arrangement of the molecules. The black line shows the phase of the sound wave, the red shows the pressure and the dots below represent the actual molecules. From Reference 2

2. Thermoacoustic Refrigeration

Thermoacoustics combines the branches of acoustics and thermodynamics together to move heat by using sound. While acoustics is primarily concerned with the macroscopic effects of sound transfer like coupled pressure and motion oscillations, thermoacoustics focuses on the microscopic temperature oscillations that accompany these pressure changes. Thermoacoustics takes advantage of these pressure oscillations to move heat on a macroscopic level. This results in a large temperature difference between the hot and cold sides of the device and causes refrigeration. The most important piece of a Thermoacoustics device is the stack. The stack consists of a large number of closely spaced surfaces that are aligned parallel to the to the resonator tube. The purpose of the stack is to provide a medium for heat transfer as the sound wave oscillates through the resonator tube. A functional cross section of the stack we used is shown in figure 6. In typical standing wave devices, the temperature differences occur over too small of an area to be noticeable. In a usual resonator tube heat transfer occurs between the walls of cylinder and the gas. However, since the vast majority of the molecules are far from the walls of the chamber, the gas particles cannot exchange heat with the wall and just oscillate in place, causing no net temperature difference. In a typical column, 99% of the air molecules are not near enough to the wall for the temperature effects to be noticeable. The purpose of the stack is to provide a medium where the walls are close enough so that each time a packet of gas moves,the temperature differential is transferred to the wall of the stack. Most stacks consist of honeycombed plastic spacers that do not conduct heat throughout the stack but rather absorb heat locally. With this property, the stack can temporarily absorb the heat transferred by the sound waves. The spacing of these designs is crucial: if the holes are too narrow, the stack will be difficult to fabricate, and the viscous properties of the air will make it difficult to transmit sound through the stack. If the walls are too far apart, then less air will be able to transfer heat to the walls of the stack, resulting in lower efficiency.

3. Thermoacoustic Cycle

The cycle by which heat transfer occurs is similar to the Stirling cycle. Figure 55 traces the basic thermoacoustic cycle for a packet of gas, a collection of gas molecules that act and move together. Starting from point 1, the packet of gas is compressed and moves to the left. As the packet is compressed, the sound wave does work on the packet of gas, providing the power for the refrigerator. When the gas packet is at maximum compression, the gas ejects the heat back into the stack since the temperature of the gas is now higher than the temperature of the stack. This phase is the refrigeration part of the cycle, moving the heat farther from the bottom of the tube. In the second phase of the cycle, the gas is returned to the initial state. As the gas packet moves back towards the right, the sound wave expands the gas. Although some work is expended to return the gas to the initial state, the heat released on the top of the stack is greater than the work expended to return the gas to the initial state. This process results in a net transfer of heat to the left side of the stack. Finally, in step 4, the packets of gas reabsorb heat from the cold reservoir to repeat the heat transfer process.

4. Theoretical thermoacoustic Refrigeration model for mobile phones.

The thermoacoustic model basically consists of heat exchangers, a resonator, and a stack (on standing wave devices) or regenerator and SASER , A SASER is the acoustic analogue of the laser. It is capable of producing highly coherent, concentrated beams of ultrasound, using methods very similar to those employed in the laser as the voiced speech of a typical adult male will have a fundamental frequency from 85 to 180 Hz, and that of a typical adult female from 165 to 255 Hz. A SASER operates on principles remarkably similar to those of a laser. A stack of thin semiconductor wafers are placed in a lattice within an acoustically reflective chamber. Upon the addition of electrons, short-wavelength (in the terahertz range) phonons are produced. Since the electrons are confined to the quantum wells existing within the lattice, the transmission of their energy depends upon the phonons they generate. As these phonons strike other layers in the lattice, they excite electrons, which produce further phonons, which go on to excite more electrons, and so on. Eventually, a very narrow beam of high-frequency ultrasound exits the device.The stack is a part consisting of small parallel channels. When the stack is placed at a certain location in the resonator, while having a standing wave in the resonator, a temperature difference can be measured across the stack. By placing heat exchangers at each side of the stack, heat can be moved. To be able to create or move heat, work must be done, and the acoustic power provides this work. When a stack is placed inside a resonator a pressure drop occurs. Interference between the incoming and reflected wave is now imperfect since there is a difference in amplitude causing the standing wave to travel little, giving the wave acoustic power. When looking at the acoustic wave, parcels of gas are adiabatic compressed and decompressed. Pressure and temperature change simultaneously; when pressure reaches a maximum or minimum, so does the temperature.

5. Conclusion

The above study indicate that acoustic refrigeration could be apply in devices such as mobile phone a detail mathematical analysis with variables should be conducted to optimize the theoretical model and mathematical model along with the design are the future scope.

6. References

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