DESIGN AND ANALYSIS OF THERMO ACOUSTIC REFRIGERATOR

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ABSTRACT

The study of how sound and heat interact is known as thermos acoustics. A thermoacoustic refrigerator is a setup that utilizes high-intensity sound waves to enhance the cooling effect. High-intensity sound waves are thought to be pressure pulsations. The material of the stack, which is contained within a resonator tube, is in close proximity to these pressure pulsations. Standing waves are created as a result of sound waves travelling through the resonator tube.

In this work, the standard modified thermo-acoustic refrigerator (TAR) is created. It has a stack, heat exchanger, thermocouple, resonator tube, and an acoustic driver (loudspeaker). The effects of a few design factors were investigated for a thermo-acoustic refrigerator system, including wave patterns, frequency, and heat exchanger. It was discovered that a sine wave pattern produced better cooling results than the other wave patterns examined. The heat exchanger's addition greatly increases the temperature reduction that the improved TAR achieves. The acoustic power, temperature drop, and velocity at the fluid's helium entrance velocity (1007, 2000, and 3000 m/s) are all calculated using CFD in this article. To determine the heat flux and temperature distribution for various materials, use thermal analysis (glass for tube, copper for heat exchangers, and stack for Mylar sheet) various models (tube with spiral type stack, spiral type stack with blower type tube, and square tube with square type stack). Thermo acoustic refrigerator 3D modelling in CREO. ANSYS analysis.

Keywords: Heat flux, Velocity, TAR, CFD, and CREO.

1. INTRODUCTION

Most people believe that a sound wave is just a series of connected pressure and position oscillations. In reality, oscillating heat flow occurs when spatial gradients in temperature oscillations, which happen in addition to pressure oscillations, exist. These vibrations together result in a wide range of "thermo acoustic" phenomena. The thermal impacts of sound in daily life are too modest to be immediately seen; for instance, the fluctuation of temperature at conversational levels of sound is only approximately 0.0001°c in amplitude. However, these thermo acoustic phenomena can be utilised to build potent heat engines and freezers when a sound wave is extremely intense and in a compressed environment. Unlike conventional engines and freezers, which use revolving turbines or pistons linked to the crankshaft, refrigerators and thermal acoustic engines lack moving parts (or at most only flexing parts without the need for sliding seals). The potential for thermal acoustic devices to be used in practical applications has been highlighted by their simplicity, reliability, and comparatively low cost. As a result, thermal acoustics is swiftly developing from a basic science research area to one with substantial practical applications. Most recently, thermo acoustic phenomena have been used in the medical industry for tissue imaging.

Thermo acoustic refrigeration uses cutting-edge acoustic technology to increase cooling capacity without using refrigerants that are harmful to the environment. The simple process of the tar is based on the expansion and compression of a gas by a sound wave. The pressure pulsations from a standing wave generate oscillatory motion of gas in the axial direction of the tube when a sound wave from a vibrating diaphragm or loudspeaker is delivered down a half wave length tube. Heat transport occurs whenever a stationary surface comes into thermal contact with a gas due to the combination of pressure oscillation and oscillatory motion of the gas. In a strong standing wave, significant amounts of heat will be transported if a little structure with a lot of surface area is positioned in the right spot this structure is sometimes referred to as a "stack," with one end heated and the other end cooled by heat transport. A functional heat pump or refrigerator can be constructed if both ends of the stack make thermal contact with heat exchangers.

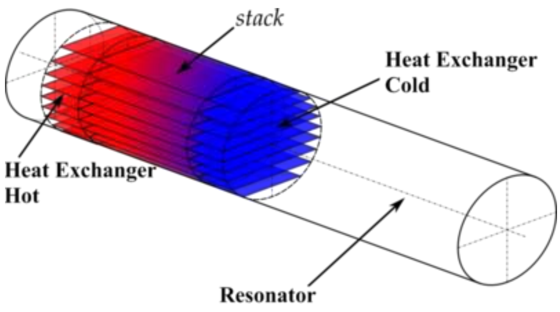

Fig: 1 Thermo Acoustic Refrigerator (TAR)

2. LITERATURE REVIEW

In the 1960s, there was an increase in interest in the use of sound waves for cooling. The physical justification for this refrigeration method is straightforward, but the study of the phenomenon and the equations that explain it are difficult. Although the thermoacoustic phenomena was first discovered more than a century ago, major research in this field only began around 20 years ago at the los alamos national laboratory. They have created many varieties of heat engines and thermoacoustic refrigerators. Several other research organizations are engaged in this field of study however, the development of such devices is still in its infancy. These gadgets are still in the early stages of development. Resonance high-amplitude sound waves in inert gases are used to pump heat in a new spacecraft cryocooler developed by garret et al[1] and deployed in the space shuttle discovery. Within their thermo acoustic equipment.

Tijani et al. [2] attained temperatures as low as -65 degrees celsius. By utilizing a binary gas mixture, they were able to analyze the impact of various significant thermoacoustic characteristics, such as the prandtl number. In a thermodynamic resonator, bailliet et al. Measured the acoustic power flow utilizing laser doppler anemometry (l.d.a) and microphone acoustic pressure measurement to create an acoustic refrigerator. They discovered that the experimental and theoretical results were in good accord. In a pulse tube refrigerator, jin and colleagues investigated the thermoacoustic phenomenon. They investigated the working fluid's impacts as well as the thermoacoustic prime mover's features. They attained a cryogenic temperature of 120 k throughout their tests.

Symko et al. [3] used a thermo acoustic refrigerator and prime mover to remove heat from an electronic circuit. By operating the thermoacoustic devices at frequencies between 4 and 24 khz, they evaluated their efficacy.

A thermoacoustic refrigerator's performance under changing loading was experimentally studied by jebali et al. [4] who then compared the experimental results to the computed data. In their studies, the cold heat exchanger's temperature was adjusted to achieve a temperature difference of between 0.5 and 10 k along the stack while the hot heat exchanger was kept at room temperature. For these temperature differences, they measured and calculated the cooling load while altering the driving frequency between 30-65 hz.

Using an acoustic loop-tube with two stacks within, sakamoto et al [5] acoustic cooler was the subject of their studies (sakamoto et al., 2005). It was decided to utilise stack 1 as a prime mover and stack 2 as a heat pump. The working fluid was an atmosphere-pressure blend of air and helium gas. A temperature reduction of about 289 k was seen by them. Additionally, they discovered that the self-sustaining sound has higher harmonics, which reduces the system's effectiveness. T

Ijani et al. [6] proposed an analytical model of the interaction between a sound wave and a solid surface. They found that the thermal relaxation dissipation at the gas is minimised when the temperature oscillations in the wall follow the temperature oscillations in the gas.

Huelsz et al. Used a single plate linear theory for the thermoacoustic phenomenon under ideal conditions. In order to calculate the plate difference between temperature and pressure waves, use formulae [7].

3. Modelling and Analysis

Computer-aided design (cad), often known as computer-aided design and drawing, is the use of computers for design and layout documentation (CADD). computer-assisted drafting is the practise of using a computer to create documents. The user is provided with input-equipment to streamline layout techniques, as well as drafting, documentation, and production approaches, by cadd software, or environments. CADD output frequently follows the shape of digital files for machining or printing tasks. Construction, production, and other industry-based software programmes typically use vector-based totally (linear) environments, whereas photo-based software programmes use raster-based totally (pixelated) environments. As a result, the advancement of CADD-based software programmes is directly correlated with the methods it seeks to save money.

3d modelling software ptc Creo, formerly known as pro/engineer, is employed by businesses that provide cad drafting services as well as mechanical engineering, design, and manufacturing. One of the first 3d cad modelling programmes to employ a rule-based parametric approach was this one. It can optimise both the development product and the design itself by using parameters, dimensions, and features to capture the behaviour of the product.

3.1 2D Model of Thermo Acoustic Refrigerator

Fig:2 Surface Model Of TAR

We took the geometry for the 2D TAR from the article "CFD simulation of a thermoacoustic engine with coiled resonator" in the journal. The 2D TAR'S dimensions are depicted in fig. Ansys workbench 14.5 was used to perform the dimensions of the 2D TAR.

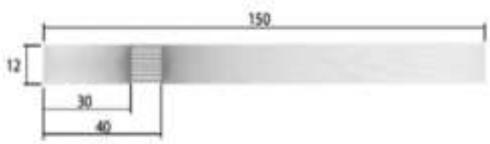

Fig3: Dimensions Of 2D TAR

ANSYS is a simulation tool for engineering (computer aided engineering). In addition to other tools aimed at assisting in the development of the product, it has tools for thermal, static, dynamic, and fatigue finite element analysis. Swanson analysis systems, inc., or SASI, was founded by dr. John a. Swanson in 1970. Its primary goal was to develop and commercialise structural physics finite element analysis software capable of simulating static (stationary), dynamic (moving), and thermal (heat transfer) problems.parallel to the expansion of computer technology and engineering needs, sasi expanded its company. The business expanded by 10% to 20% the year before being sold in 1994. The new owners chose ansys, the industry-leading software from sasi, as their main offering and changed the company's name to ansys, inc. In the field of fluid mechanics known as computational fluid dynamics or CFD, issues involving fluid flows are solved and analysed using numerical methods and algorithms. The computations necessary to simulate how liquids and gases interact with surfaces determined by boundary conditions are done on computers. Better solutions are possible with high-speed supercomputers. The outcome of ongoing research is software that improves the accuracy and speed of complex modelling scenarios, such as transonic or turbulent flows. The initial experimental validation of such software is conducted in a wind tunnel, and the final experimental validation is conducted using full-scale testing, such as flight tests.

4. CFD ANALYSIS OF THERMO ACOUSTIC REFRIGERATION SYSTEM

4.1 Imported Model

The model listed below was loaded into Ansys.

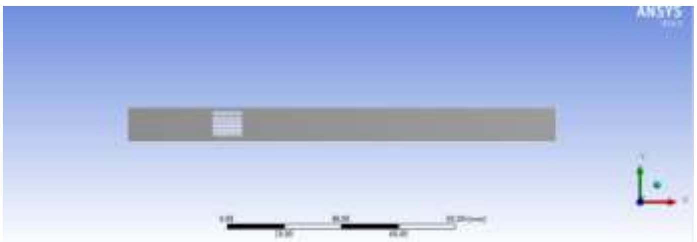

Fig:4 Imported Model

4.2 Boundary Conditions

Ansys workbench 14.5 was used to analyse the 2D TAR. In the fluid flow module (fluent). Name the sections for the stack side's INLET and the opposite end's OUTLET. After that, fine-mesh for the best solution. After that, select the density-based solver for planes and steady solutions in general under setup. Select k-epsilon (2 eqn) in the viscous model, switch on the energy equation in the model, and then choose broadband noise sources to apply in the acoustics section. Assign the air as the material and enter (1007,2000,3000 m/s) for the far-field speed in acoustics.

Give it an initial velocity of 1007 m/s for the inlet select velocity under boundary conditions In the thermal, the temperature is listed as 328k.The solution will then be initialised when you click initialization. To complete the calculation, we must choose the number of iterations—in this case, 100—and then click the calculate button. The pressure ranges, acoustic power, and heat transfer coefficient for the specified inlet velocity must be known. Thermal analysis uses the heat transfer coefficient discovered by cfd research to determine heat flux and temperature distribution.

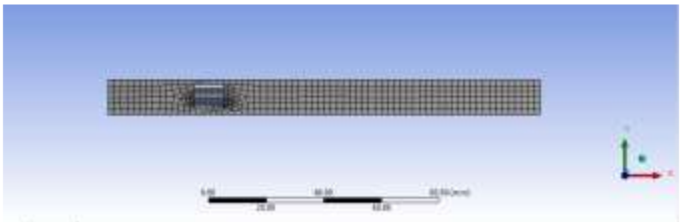

Fig :5 Meshed Model

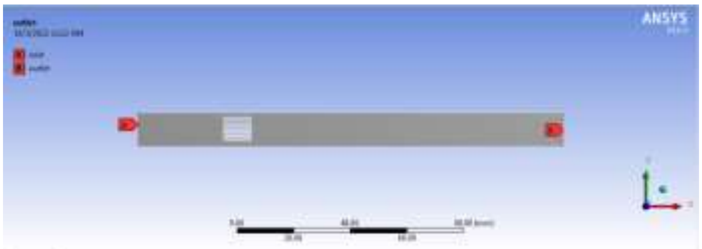

Fig: 6 Inlet and Outlet Conditions

4.1 At Helium Velocity -3000m/S

4.1.1 Pressure

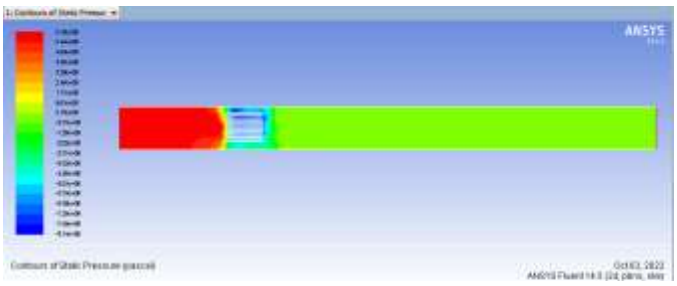

Fig: 7 Pressure at Velocity 3000

4.1.2 Velocity

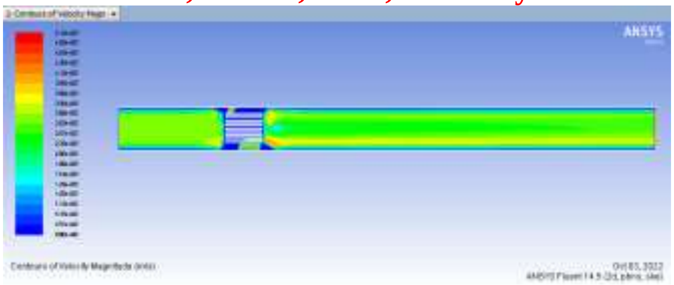

Fig: 8 Velocity

4.1.3 Heat Transfer Coefficient

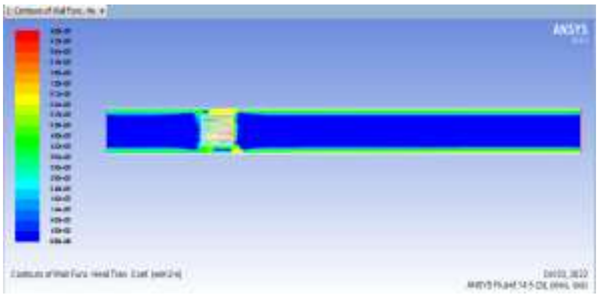

Fig: 9 Heat Transfer Coefficient

4.1.4 Acoustic Power Level

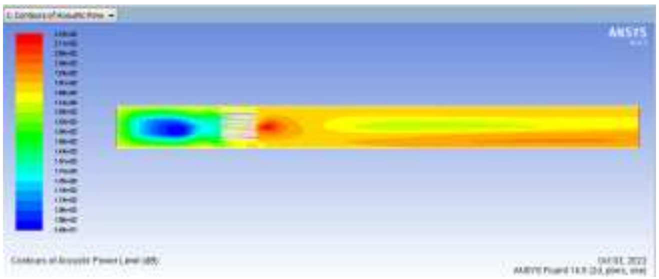

Fig: 10 Acoustic Power Level

4.1.5 Acoustic Power

Fig: 11 Acoustic Power

4.1.6 Heat Transfer Rate

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Total Heat Transfer Rate                    (w)
-------------------------- --------------------
                     inlet            82109.594
                    outlet           -82105.344
              wall-split.1_                   0
          ---------------- --------------------
                       Net                 4.25
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Fig: 12 Net Heat Transfer Rate

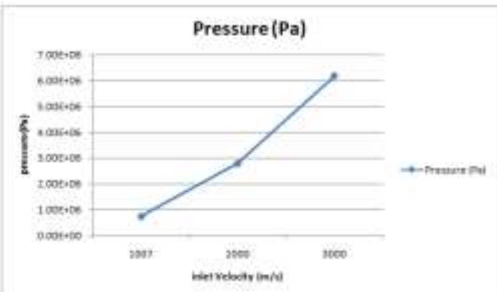
4.2 CFD Analysis Results

Table: 1 CFD Analysis Results

Inlet Velocity(M/S)	Pressure (Pa)	Outlet Velocity(M/S)	Heat Transfer Coefficient	Acoustic Power Level	Acoustic Power	Heat Transfer Rate
1007	7.23e+05	1.73e+03	4.14e+03	1.79e+02	1.47e+06	0.96
2000	2.78e+06	3.43e+03	7.00e+03	2.03e+02	3.79e+06	1.394
3000	6.18e+06	5.15e+03	9.60e+03	2.18e+03	1.01e+10	4.25

The determined Heat transfer coefficient is used in the thermal analysis of the tar. The figures above show the acoustic power, which is what is actually producing the temperature gradient.

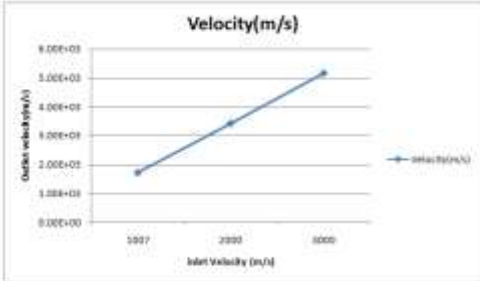
4.2.1 Inlet Velocity Versus Pressure



Graph: 1 Inlet Velocity VS Pressure

The graph above illustrates how pressure levels vary at various input velocities (1007, 2000, and 3000 m/s). Looking at this graph, observe that pressure rises as inlet velocity rises.

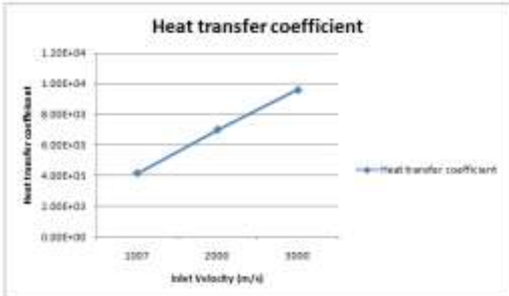
4.2.2 Inlet Velocities Versus Outlet Velocity (m/s)



Graph: 2 Inlet Velocities Vs Outlet Velocity

The aforementioned graph illustrates how the outflow velocity varies at various entrance velocities (1007, 2000, and 3000 m/s). Looking at this graph, observe that outflow velocity rises as inlet velocity rises.

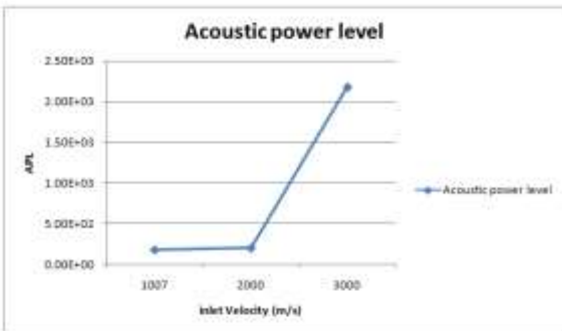
4.2.3 Inlet Velocity Versus Heat Transfer Coefficient



Graph: 3 Inlet Velocity Vs Heat Transfer Coefficient

The heat transfer coefficient is depicted in the graph above for various inlet velocities (1007, 2000, and 3000 m/s). Looking at this graph, it is clear that the heat transfer coefficient rises as the input velocity rises.

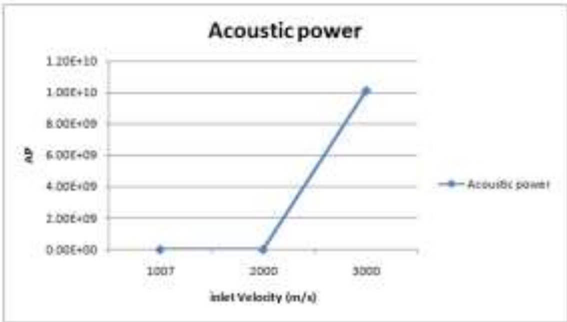
4.2.4 Inlet Velocities Versus Acoustic Power Level



Graph: 4 Inlet Velocity Versus Acoustic Power Level

Inlet velocities (1007, 2000, and 3000 m/s) are shown against acoustic power level in the graph above. This graph shows that at a helium inflow velocity of 3000 m/s, the acoustic power level changes significantly.

4.2.5 Inlet Velocities Versus Acoustic Power



Graph: 5 Inlet Velocities Versus Acoustic Power

Inlet velocities (1007, 2000, and 3000 m/s) are shown against acoustic power in the graph above. This graph shows that the acoustic power steadily increases between helium inlet velocities of 2000 and 3000 m/s.

5. THERMAL ANALYSIS OF VARIED TYPES OF TAR

5.1Spiral Type Stack

Resonator dimensions: 250mm length, 100mm outer diameter, and 95mm inner diameter. The stack is measured as rectangular parts that are 100mm long and have varied widths across their cross-sections. The same design element is imported with the. Igs extension into the steady state thermal geometry module. Analysis of the glass for the resonator and the copper for the stack materials. Next, carry out the thermal analysis. Then solve the model and include the thermal heat transfer coefficient, heat flux, and temperature distribution in the result.

5.1.1Temperature

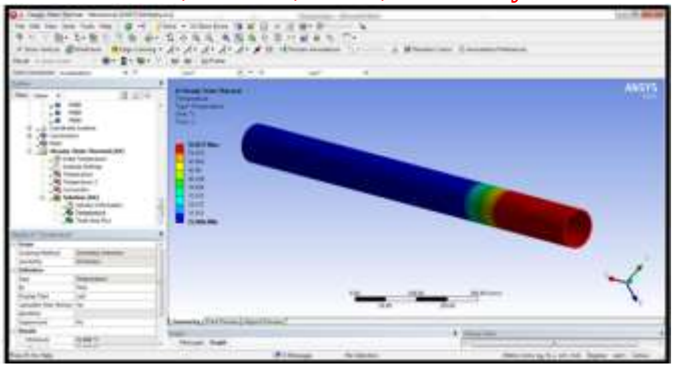


Fig: 12 Temperature Distribution

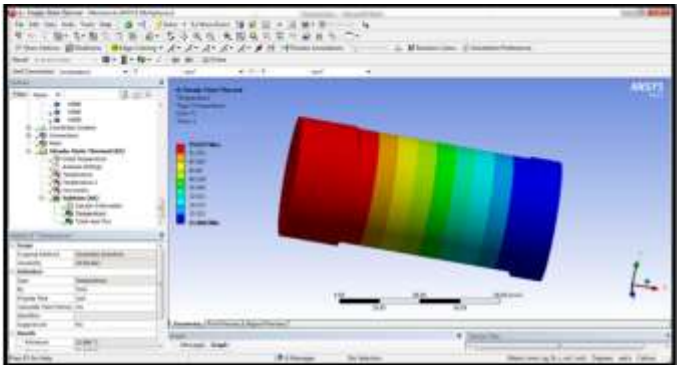


Fig: 13 Temperature Distribution of Stack

5.1.2 Heat Flux

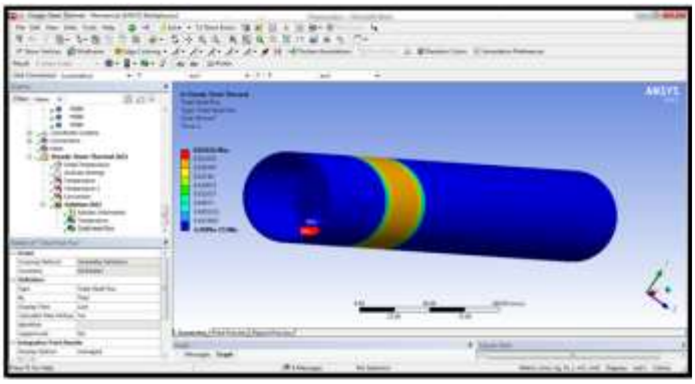


Fig: 14 Heat Flux

5.2 Rectangular Type

The rectangular tar has two rectangles, one measuring 100mm*95mm and the other 95mm*90mm. Stack merely has a rectangle-shaped cross-section. The exact same design component is imported with an extension of.iges into the steady state thermal geometry module. Glass is used for the resonator chamber and mylar sheet being used for the rectangular stack. The meshing is finished next. Then solve the model and include the thermal heat transfer coefficient, heat flux, and temperature distribution in the result.

5.2.1 Meshed Model

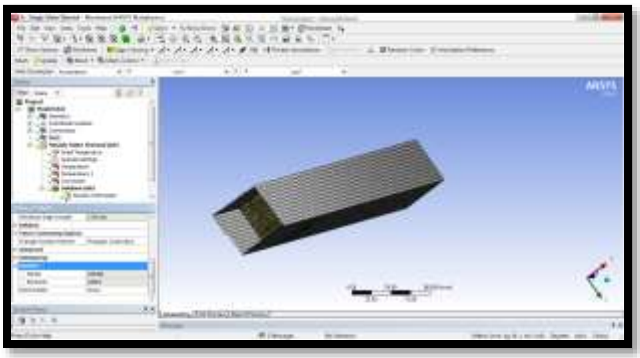


Fig: 15 Meshed Model

5.2.2 Boundary Conditions

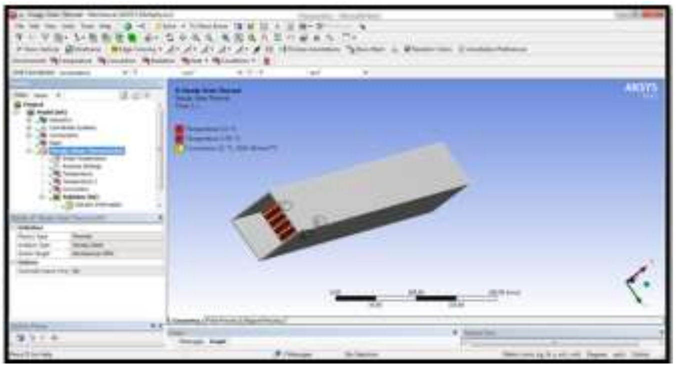


Fig: 16 Boundary Conditions

5.2.3 Temperature Distribution

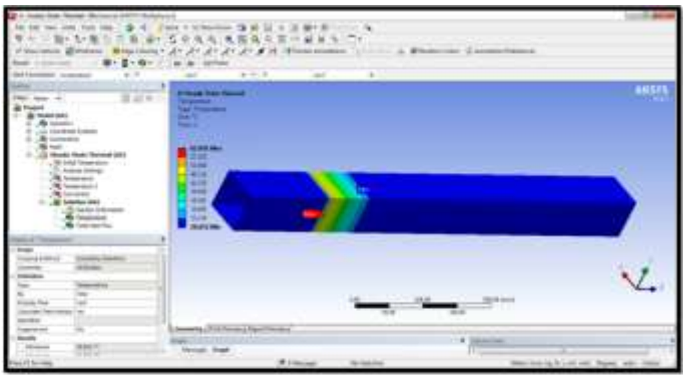


Fig: 17 Temperature Distribution

5.2.4 Heat Flux

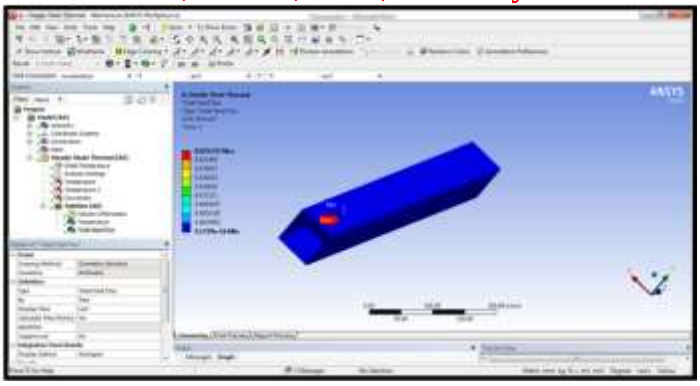


Fig: 18 Heat Flux

5.3 Blower Type Tube with Spiral Type Stack

In this created the same circular section and added a blower surface. The blower can then be made to resemble a funnel by rotating the shaft tool around the axis of the circular section. The same design element is imported with the. igs extension into the steady state thermal geometry module. navigate to the geometry model. choose the portion, then give each part a material. before that, add the components, such as glass, mylar sheet, copper alloy, and heat transfer coefficient. The meshing is finished next. Give the inflow temperature at the stack faces, which is 55 degrees Celsius. Include the thermal heat transfer coefficient that was discovered by the 2D tar's cfd study as well. then solve the model and include the thermal heat transfer coefficient, heat flux, and temperature distribution in the result. we can get the numerous answers.

5.3.1 Meshed Model

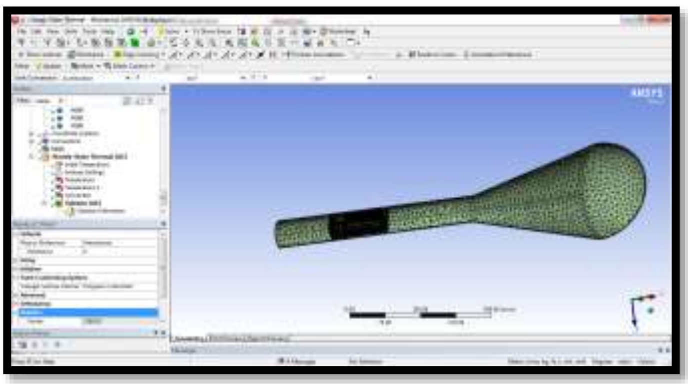


Fig: 19 Meshed Model

5.3.2 Boundary Conditions

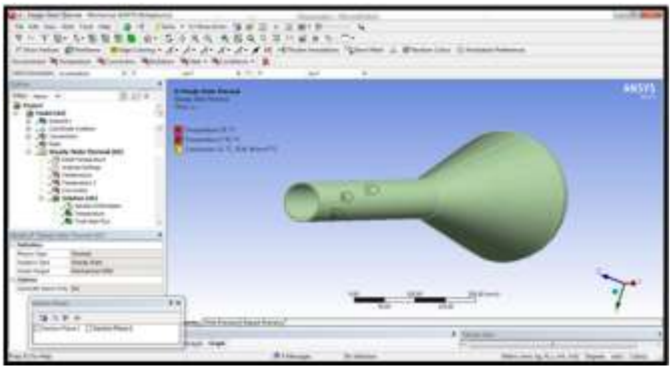


Fig: 20 Boundary Conditions

5.3.3 Temperature

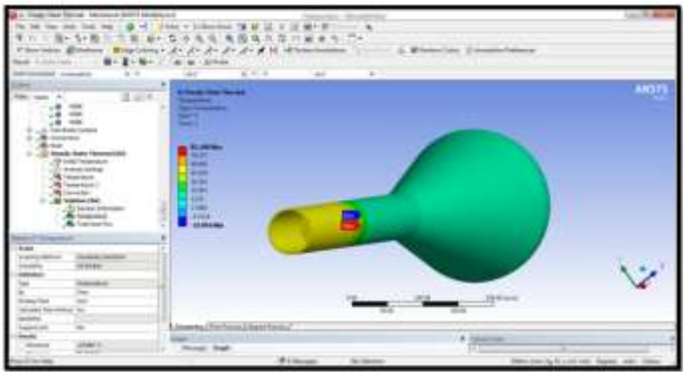


Fig: 21 Temperature Distribution

5.3.4 Heat Flux

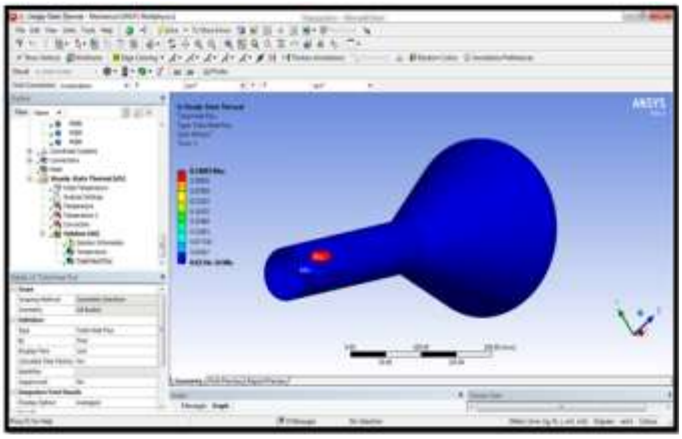


Fig: 22 Heat Flux

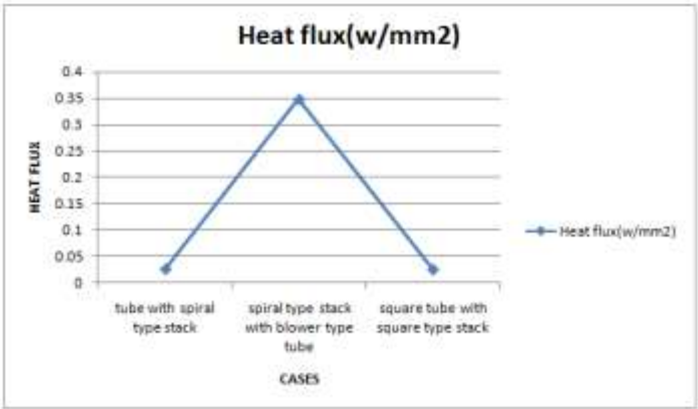
5.4 Thermal Analysis Results

The findings of the analysis of several types of tar are shown in the table below.

Model	Temperature (^{0}C)		Heat Flux(W/Mm^2)
	Max	Min	
Tube With Spiral Type Stack	55.037	21.866	0.02616
Spiral Type Stack with Blower Type Tube	81.448	-19.994	0.34803
Square Tube with Square Type Stack	61.841	20.652	0.025247

Table 2: Thermal Analysis Results

5.6 Cases Versus Heat Flux



Graph :6 Cases Versus Heat Flux

Examining the findings of the thermal analysis spiral type stacks with blower type tubes have a higher heat flux. This might be caused by wider wave propagation. It is noticed that a greater temperature differential when using a blower, which may be related to geometric shape.

7. CONCLUSIONS

Since 1980, the research community has paid close attention to the construction and operation of thermo-acoustic refrigerators. Once the advancements in design and technology are accomplished, this environmentally friendly technology may eventually replace traditional refrigerators. The phrase "thermo-acoustic" refers to the result of sound waves generating a heat gradient and vice versa.

In this research, CFD analysis was used to calculate the fluid's mass flow rate, velocity, heat transfer rate, heat transfer coefficient, and acoustic power. He inlet speed.

Thermal analysis is used to calculate the heat flux and temperature distribution for various cross-sectional geometries (tube with spiral type stack, spiral type stack with blower type tube, and square tube with square type stack).

The input velocities are increased by observing the CFD study, which raises the acoustic power and acoustic power level. the pressure drops, velocity, and mass flow rate all rise as the inflow velocities do as well.

By looking at the aforementioned thermal analysis results, the maximum temperature distribution is higher for spiral-stacked blower-type tubes.

REFERENCES

[1] Tong huana,b, hu jianyinga, zhang limina, and luo ercanga, "experimental study of an acoustic resonant cooling system," in proceedings of the 25th international conference on cryogenic engineering and the international conference on cryogenic materials, icec 25-icmc 2014, physics procedia 67 (2015), pp. 445–450.

[2] Thermo-Acoustic Refrigeration GSET research journal, 2006; jonathan newman, bob cariste, alejandro queiruga, isaac davis, ben plotnick, michael gordon, and sidney san martin.

[3] P. Yang, M. Fang, And Y.W. Liu, "optimization of a phase adjuster in a thermo-acoustic stirling engine using response surface approach," in energy procedia 61 (2014), pp. 1772–1775, the 6th international conference on applied energy (ICAE2014).

[4] "Experimental examinations of the performance of a standing wave thermo-acoustic refrigerator based on multi-objective genetic algorithm optimised parameters," in applied thermal engineering 100 (23 February 2016), Pp. 296-303.

[5] Matthieu Guedra, Flavio C. Bannwart, Guillaume Penelet, And Pierrick Lotton, "Parameter estimate for the characterisation of thermo-acoustic stacks and regenerators," applied thermal engineering 80 (February 2015), Pp. 229–237.

[6] Mohamed Gamal Mekdad and Abdulkareem Sh. Mahdi Al- obaidi's design and analysis of a thermo-acoustic refrigerator was published in the august 2013 issue of the international journal of advancements in research & technology, Vol-3.

[7] Nasser Yassen, "impact of temperature gradient on thermoacoustics refrigerator," international conference on technologies and materials for renewable energy, environment and sustainability, 2015, 1182–1191; Energy procedia, 2015, 1182–1191 (TMREES15).

[8] Thermoacoustic refrigeration as an environmentally friendly alternative, applied thermal engineering, 2010, 119–126. Laura A. Schaefer, Florian Zink, And Jeffrey S. Vipperman.

[9] Florian Zink, Laura A. Schaefer, Jeffrey S. Vipperman, thermoacoustic cooling cfd simulation, international journal of heat and mass transfer, 2010, 3940–3946.

[10] N. M. Hariharan, P. Sivashanmugam, and s. Kasthurirengan, "impact of stack geometry and resonator length on the performance of thermoacoustic engine," applied acoustics, 2012,1052-1058