DESIGN AND ANALYSIS OF THERMO-ACOUSTIC REFRIGERATOR

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ABSTRACT: In the present scenario, mostly we are using Vapour Compression Refrigerators (VCR) for preserving.But, the conventional refrigerators releases the ChloroFluoro Carbons. The release of CFCs leads to the depletion of ozone layer. So, the research on the alternatives has been going to replace the conventional refrigerators. In the Alternatives, Thermo-Acoustic Refrigerator (TAR) is one of the best device to replace existing device. In this project Thermal analysis of various types of TAR has been done toobtainthe optimum design based on temperature distribution.Heat flux and temperature distribution were obtained for various TARs proposed.

In this paper we have done CFD analysis to determine the acoustic power, temperature drop and velocity at fluids Helium inlet velocity (1007m/s) and Thermal analysis to determine the heat flux and temperature distribution for different materials (glass for tube, copper for stack different models like tube with spiral type stack, spiral type stack with blower type tube and square tube with square type stack).From the results we got, It was found that Blower type resonator tube with circular stack lead to superior cooling effects compared to other shapes of resonator tubes tested.

Keywords:*Thermo-Acoustic Refrigerator, stack, resonator tube, acoustic power, heat flux, temperature distribution*

I.INTRODUCTION

A thermo acoustic refrigerator (TAR) is a device which will be taken sound waves in order to produce the cooling effect. In a TAR, Generally the working fluid could be helium-argon mixture, and the compressor is replaced by a loudspeaker. The advantages of this kind of refrigeration cycle are two-fold. The helium and argon are inert, environmentally friendly gases, unlike many of the common refrigerants. The loudspeaker is a simple device that is more durable than a compressor and is the TAR's only moving part.

One of the work on TAR in which, they showed that curvature in the resonator influences both the amplitude and the frequency of the sound waves, depending on the severity of curvature. Both effects must be considered when thermoacoustic refrigerators are designed, because a small change in operating conditions can result in drastic changes in performance [1]. There was four degrees drop in temperature at the cold chamber. For every three degrees rise in temperature at hot end there was one degree drop at cold end. The drop in temperature increases with increase in time [2].

This experiment proved that thermo-acoustic refrigerators indeed work. Additionally, this experiment did yield some discoveries regarding the efficiency of Thermo-AcousticRefrigeration. It was revealed that finding the optimal frequency is essential for the maximization of efficiency [3].They have developed different types of thermo acoustic refrigerators and heat engines. Only very limited research groups are working in this area. However, the development of such devices is still at preliminary stages. Garret et al developed a new space craft cryocooler, which uses resonance high-amplitude sound waves in inert gases to pump heat, which was used in the space shuttle discovery. Tijani et al. achieved temperature as low as -65˚C in their thermo acoustic devices. They used it to study the effect of some important thermo acoustic parameters, such as the prandtl number by using binary gas mixture. Bailliet et al. measured the acoustic power flow in the resonator of a thermo acoustic refrigerator by using Laser Doppler Anemometry (L.D.A) together with microphone acoustic pressure measurement [4].

II.METHODOLOGY

2.1 MODELLING AND CFD ANLYSIS OF THERMO-ACOUSTIC REFRIGERATOR:

2.1.1 GEOMETRY AND ANALYSIS:-

For the Geometry of 2D TAR we have taken it from the journal on"CFD simulation of a thermoacoustic engine with coiled resonator". The dimensions of the 2D TAR are shown in the *Fig1*.

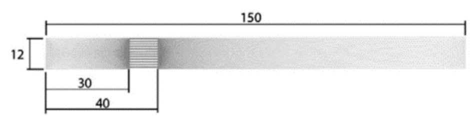
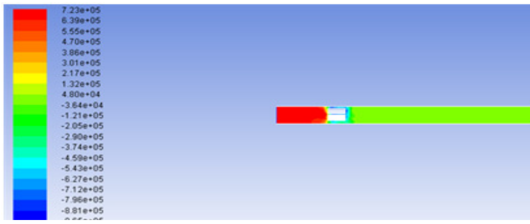


Fig1: Dimensions of 2D TAR

2.1.2 BOUNDARY CONDITIONS:

The analysis of 2D TAR was performed in ANSYS Workbench 14.5. In the module of Fluid Flow (Fluent). Give the Named sections for stack side as INLET and other end as OUTLET. Then do the fine meshing for appropriate solution. Next go to setup then select density based solver of plane and steady solution in general.Go to model turn on the energy equation, in viscous model we need to select k-epsilon (2 eqn) and then in acoustics select Broadband Noise Sources apply it. Give the Far-Field speed in acoustics as 1007m/s, select the air in materials.

In Boundary conditions, for inlet select velocity inlet give it 1007m/s in initial velocity. In the thermal give temperature as 333K. Then click on initialization to initialize the solution. Finally in run calculation we need to select the no. of iterations we have taken the 100iterations then click on calculate option. In order to know the ranges the pressure ranges, Acoustic power and Heat transfer coefficient for the given inlet velocity. The Heat Transfer Coefficient obtained from the CFD analysis used in Thermal Analysisin order to get Heat Flux and temperature distribution.



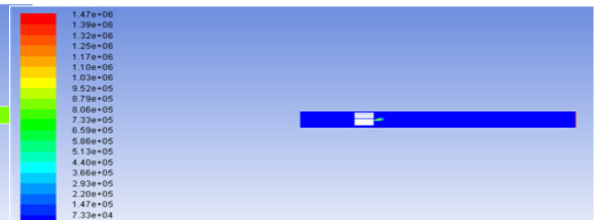


Fig 2: Pressure distributionFig 3: Contours of Acoustic Power

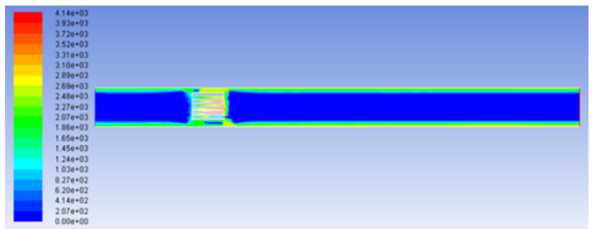


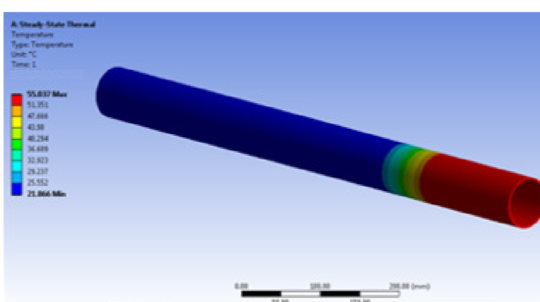
Fig 4 Contours of Wall Func. Heat Transfer Coef.

2.2 MODELLING AND THERMAL ANALYSIS OF VARIOUS TYPES OF TAR:

In this analysis we have designed two components for each section such as Stack and respective section like rectangle, circular and Blower type.

2.2.1 ANALYSIS OF CIRCULAR TAR:

Dimensions of resonator, 85mm as inner diameter, 90.86mm as outer diameter and 250mm length. The Dimensions of the stack is taken as 100mm length, rectangular sections of varying throughout the cross-section of the stack.The same design part is actually imported in the module of steady state thermal, geometry with an extension of .igs. Analysis done on the material glass for resonator and copper for the stack. Then, proceed for the Thermal Analysis.Then Solve the model, in the solution add temperature distribution, heat flux, thermal heat transfer coefficient. We have obtained the results.



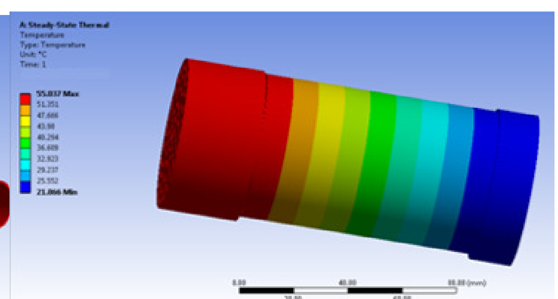


Fig 5: Temperature distribution of circular TARFig 6: Temperature distribution of spiral stack

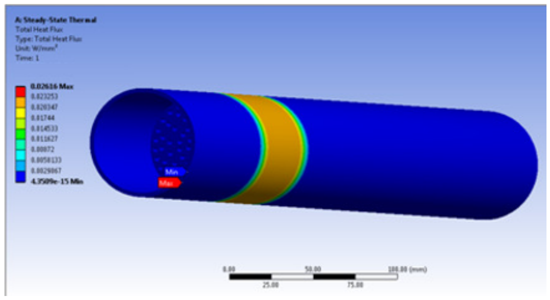
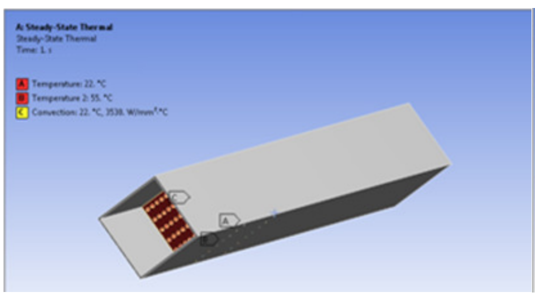


Fig 7: Total Heat Flux for circular TAR

2.2.2ANALYSIS OF RECTANGULAR TAR:

The dimensions of rectangular TAR are 90mm*85mm outer rectangle and 85mm*80mm inner rectangle. Stack is also rectangle cross-section only. The same design part is actually imported in the module of steady state thermal, geometry with an extension of .IGES. Copper alloy is assigned to Rectangular stack and glass for the resonator chamber. After that meshing is done. Then Solve the model, in the solution add temperature distribution, heat flux, thermal heat transfer coefficient. We can obtain the various solutions



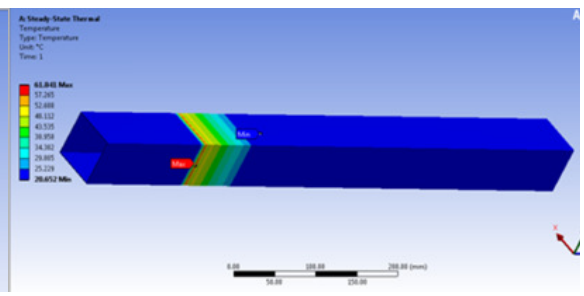


Fig 8: Boundary conditions for Rectangular TAR Fig 9: Temperature distribution for Rectangular TAR

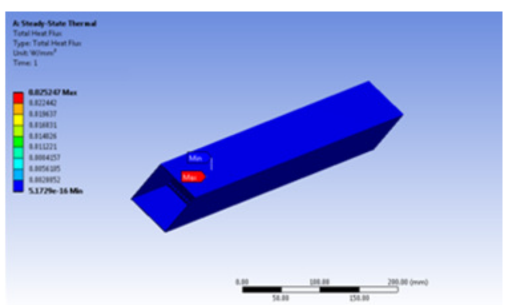
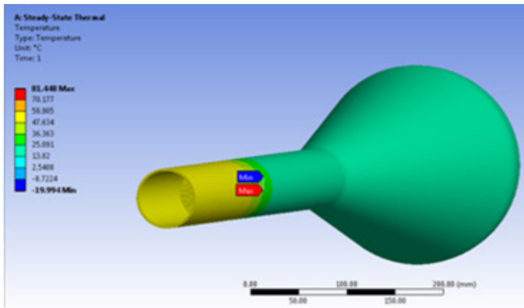


Fig 10: Total Heat Flux for Rectangular TAR

2.2.3 ANALYSIS OF BLOWER TAR:

We have designed the same circular section and add the surface of blower. Then using the shaft tool about the axis of the circular section then we can obtain the shape of the blower similar to funnel. The same design part is actually imported in the module of steady state thermal, geometry with an extension of .igs. Go to model in the geometry select the part then assign the material for each part. Before that add the materials i.e. copper alloy and add glass, add heat transfer coefficient. After that meshing is done. Give the temperature inlet at faces of stack i.e. 60 degree Celsius. Also add the thermal heat transfer coefficient obtained from the CFD analysis of the 2D TAR. Then Solve the model, in the solution add temperature distribution, heat flux, thermal heat transfer coefficient. We can obtain the various solutions.



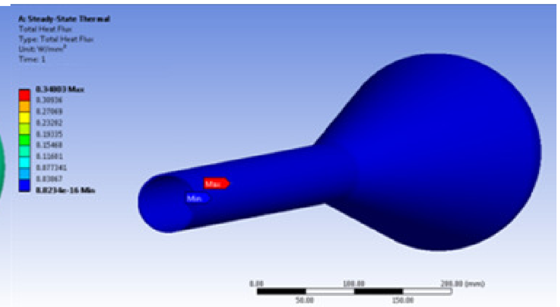


Fig 11: Temperature distribution for Blower type TAR Fig 12: Total Heat Flux for Blower type TAR

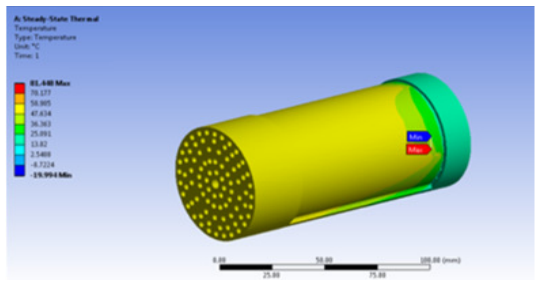


Fig 13: Temperature distribution for spiral stack

III. RESULTS AND DISCUSSION

3.1 CFD ANALYSIS RESULTS:

Parameter	Pressure (Pa)	Velocity (m/s)	Heat transfer coefficient (w/m2-k)	Acoustic power (w/m3)	Mass flow rate(kg/s)	Heat transfer rate(W)
Results	1.03e+06	2.03e+03	0.0014	7.11e+14	9.81824	2947.3125

The Heat Transfer Coefficient obtained is used in the Thermal Analysis of the TAR. From the above results we can observe the Acoustic Power which actually causing the Temperature gradient.

3.2 THERMAL ANALYSIS RESULTS:

Model	Temperature (^0C)		Heat flux(w/mm^2)
	Max	Min	
Tube With Spiral Type Stack	55.037	21.866	0.02616
Square Tube With Square Type Stack	61.841	20.652	0.025247
Spiral Type Stack With Blower Type Tube	81.448	-19.994	0.34803

From the Results obtained in the Thermal Analysis, we can see that the Heat Flux is more for the Spiral Type Stack with Blower Type Tube. This may be attributed to wider wave propagation. Temperature difference also we got more in Blower type it may be due to geometrical shape.

IV. CONCLUSION AND FUTURE SCOPE

In the CFD Analysis, we found the Heat Transfer Coefficient which is used in the Thermal analysis. In the, Thermal analysis we have determined the heat flux and temperature distribution for different cross sectional geometries (tube with spiral type stack, spiral type stack with blower type tube and square tube with square type stack).

Based on the results obtained, we have concluded that the spiral type stack with blower type tube is obtained the desired properties.

VI. REFERENCES

[1] CFD simulation of a thermoacoustic engine with coiled resonator, University of Pittsburgh, Department of Mechanical Engineering and Material Science, 225 Benedum Hall, Pittsburgh, PA 15261, United States.

[2] Thermo Acoustic Refrigeration Dept. Of Mechanical Engineering Matrusri Engineering College Affiliated to Osmania University Saidabad, Hyderabad, Telangana, India

[3] Jonathan Newman, Bob Cariste, Alejandro Queiruga, Isaac Davis, Ben Plotnick, Michael Gordon, and Sidney San Martín,"Thermo-acoustic Refrigeration GSET Research Journal" 2006.

[4] P Yang, M Fang, Y.W Liu, "Optimization of a phase adjuster in a thermo-acoustic stirling engine using response surface methodology" The 6th International Conference on Applied Energy – ICAE2014, Energy Procedia 61 (2014), pp. 1772 – 1775.

[5] Nor AtiqahZolpakar ,NormahMohd-Ghazali , Robiah Ahmad, "Experimental investigations of the performance of a standing wave thermo-acoustic refrigerator based on multi-objective genetic algorithm optimized parameters" Applied Thermal Engineering 100 (23 February ,2016), pp. 296–303.

[6] MatthieuGu_edra, Flavio C. Bannwart, Guillaume Penelet, PierrickLotton, "Parameter estimation for the characterization of thermo-acoustic stacks and regenerators" Applied Thermal Engineering 80 (4February, 2015), pp. 229-237.

[7] Mohamed Gamal Mekdad, Abdulkareem Sh. Mahdi Al-Obaidi, "Design and Analysis of A Thermo-Acoustic Refrigerator" International Journal of Advancements in Research & Technology, Vol-3 August 2013.

[8] P.H. Ceperley, ApistonlessStirling engine — the traveling wave heat engine, Journal of the Acoustical Society of America 66 (5) (1979) 1508–1513.

[9] N. Kagawa, Regenerative Thermal Machines, International Institute for Refrigeration, Paris, 2000.

[10] M. E. Poese, R. W. Smith, S. L. Garrett, R. van Gerwen, P. Gosselin, Thermoacoustic refrigeration for ice cream sales, in: Proceedings of 6th IIR Gustav Lorentzen Conference, 2004.

[11] C. Herman, Z. Travnicek, Cool sound: the future of refrigeration Thermodynamic and heat transfer issues in thermoacoustic refrigeration 42 (2006) 492–500.

[12] Design And Fabrication Of Thermo Acoustic Refrigeration System SreeneshValiyandi Department of Mechanical Engineering , College of Engineering Thalassery, Eranholi P O Thalassery, Kannur Kerala, (India) [IJARSE-16].

[13] C. Herman, Z. Travnicek, Cool sound: the future of refrigeration? Thermodynamic and heat transfer issues in thermoacoustic refrigeration, Heat and Mass Transfer 42 (2006) 492–500.

[14] J.A. Lycklama À Nijeholt, M.E. Tijani, S. Spoelstra, Simulation of traveling wave thermoacoustic engine using computational fluid dynamics, Journal of the Acoustical Society of America 118 (4) (2005) 2265–2270.

[15] CC. Hantschk, D. Vortmeyer, Numerical simulation of self-excited thermoacoustic instabilities in a rijke tube, Journal of Sound and Vibration 277 (9) (1999) 758–763.