ISSN: 0974-5823 Vol. 7 No. 10 October, 2022

International Journal of Mechanical Engineering

Analysis of Vortex Tube in Different Dimensions, Materials and Fluids

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Abstract— The vortex tube also known as Ranque tube, with no moving parts and reliable device it produces hot and cold gas streams simultaneously from the source of the compressed gas, An experiment has been conducted to evaluate the thermodynamic analysis of the vortex tube.The device can be used for cooling and heating. The thermal separation inside the counter flow vortex tube can be performed as a working model of computational fluid dynamics to investigate the flow phenomenon. Mostly this type of model is used to simulate the physical behaviour of flow such as temperature and pressure inside. The simulation results of the vortex tube can be clearly derived according to the two regions of high and low air temperature. This can be seen through the graphical visualization so it can be better made in the laboratory by predicting it by a temperature simulation model. Many researchers have done this type of test in different ways. In this we have done CFD analysis on the generic design of vortex tube using ANSYS CFX

Index Terms— Vortex tube, temperature separation. Cooling machine, Temperature drop,

I. INTRODUCTION

The vortex tube is a fundamentally direct contraption with no moving parts that are prepared for confining a high-pressure stream into two lower pressure streams with different energies, ordinarily displayed as a qualification in temperatures. The vortex tube is fairly inefficient as a free cooling device yet it could transform into a huge portion of a refrigeration system when used as a choice rather than the common expansion contraption. A cycle expanded with a vortex tube can offer a couple of advantages including viable movement over the Joule-Thomson inversion twist, relative wantonness toward heat exchanger size, and the ability to work with a lower pressure extent. How much these advantages are recognized depends upon the cycle plan, the fluid properties, the functioning circumstances, and the lead of the vortex tube. The vortex tube ha s been oppressing of studies in light of its massive applications in planning, for instance, to cool bits of machines, refrigeration, cool electric or electronic control cabinets, cooling of provisions in research places overseeing shaky manufactured mixtures, chill environmental chambers, cool food sources, liquefaction of combustible gas and cooling suits. In addition, the shortfall of moving parts, power and others benefits make the contraption appealing for different phenomenal applications where ease, strength, relentless quality and general prosperity are needed. One more critical motivation for the examination of vortex tubes is stressed over the multifaceted design of the energy separation wonder in the compressible and tempestuous stream.

II. LITERATURE REVIEW

Gautam Agarwal et. al. (2021) In this report they explain environmental change expects us to remove many of the requires we create and increase reasonable innovations to sequester CO^2 from the profoundly weaken barometrical focuses. CO^2 gas freezes at −78.5° C and subsequently, on a fundamental level, can be isolated from air, the nitrogen where starts to freeze at

−210 °C. Vortex tubes were explored as a likely technique for carbon catch through a progression of mathematical and procedural enhancements. Encompassing air is packed and afterwards isolated by temperature because of the activity of the Vortex Tube. B. Ivanov et. al. (2021) they have successful development of the livestock industry directly depends on veterinary and sanitary wellbeing. There are different types of disinfectantson the market, but their use in the same doses or overuse rates leads to increasing antimicrobial resistance of microorganisms. We propose the design of a nanoscalephononic analog of the Ranque-Hilsch vortex tube in which heat flowing at a given temperature is split into two different streams going to the two ends of the device, inducing a temperature asymmetry. Karthik A. V. & Vighnesha Nayak (2021) One of the outlet streams is the peripheral stream that has higher temperature than the inlet while the other outlet stream is the inner or corestream that has temperature lower than the inlet. Various theories have been put forwarded by many investigators to explain the mechanism of this temperature separation in vortex tube... Xiangji Guo et al (2021) Vortex tube is a non conventional cooling device which produces cold air and hot air from the source of compressed air without affecting the environment. When air with high pressure is tangentially injected into vortex chamber, a strong vortex flow will be created which will be split into two air streams. Upendra Sharan et al (2021) the vortex tube also known as Ranque tube is a remarkably a simple device, reliable (since no moving parts) and produces hot and cold gas streams simultaneously from the source of the compressed gas.

Gregory Wallace et al (2021) In the experimental parametric tests, the air flow rate increased with pressure ratio, with 14 SLPM (0.3 g/s) at a pressure ratio of 2, with 25 SLPM (0.5 g/s) at a pressure ratio of 3, and 35 SLPM (0.7 g/s) at a pressure ratio of 4. Experimental results for the outlet temperature variations as functions of cold fraction and pressure ratio are given in .The observed trends are typical for vortex tubes: Aditya Gosukonda et al.(2021) The cooling effect of vortex tube is high when inlet pressure is high and when the hot endopening is small. It is clear that always the performance of vortex tube is directly proportional to inlet compressed air. Placing a tangential nozzle in cylinder is complicated job; this complication can be avoided by Vortex generator

Abhinav giri ,dr. Piyush jaiswa (2020) According to the experimental data, graphical dependencies are constructed showing the effect of the working pressure in the vortex device on heating of compressed air at the inlet to the sprayer, the degree of heating of the disinfectant liquid by compressed hot air, and the kinematic viscosity of the disinfectant liquid versus its temperature. The droplet sizes atdifferent conditions of the sprayer operation are obtained.Hua Zhu et al (2020) Numerical simulations were carried out to study the heat transfer and friction characteristics for Stirling engine heater tubes with th ree-dimensional internal extended micro-rib. During the numerical simulations, phase angle in a cycle ranged from 0° to 360°. Alfan Sarifudin et al (2020) In this paper they use the RaqueHilsch Vortex Tube (RHVT) is a heat pump system that usesthe phenomenon of compressed vortex airflow in a tube for cooling and heating. This study aims to determine the effect of pressure and fraction on RHVT by cooling the surface of the hot tube naturally and forcefully.

Akash Nandargi et al (2020) On their view vortex tube is a simple energy separating device which causes heat separation between two air streams and is compact and simple to produce and to operate. Even after extensive research the efficiency of such a system, in refrigeration is very low. The phenomenon of temperature distribution in a confined steadyrotating gas flows is called Ranque-Hilsch effect. Muhammad Abdul Qyyum et al (2020) a vortex tube is a thermo fluidic device that generates cold and hot streams from a single injection of compressed gas. This interesting phenomenon of energy separation is due to fluid dynamic effects. In this study, the optimization of the vortex tube geometry was performed to investigate the potential applications of the vortex tube as an expansion device in natural gas processing and air separation industries. Velocity streamlines and temperature distributions of the separated air stream were obtained for different control valve shapes located at a hot end.Yunpeng Xuea,b et al (2020). In a vortex tube, the energy separation is a combined result of different factors. As classical fluid mechanics phenomenon, understanding of the complex helical flow mechanism within a vortex tube is a necessary foundation. P. K. V. S. Subramanyeswararao (2020) when compressedair flows tangentially into the vortex chamber through inletnozzles it splits in to hot and cold air streams. There are threeregions in the tube. In region one fluid enters, second region is cold and third region is hot.

Bazgir et. al. (2019) In this paper writer for the most part attempt to show that utilization of a few choppiness models influence the temperature at the state of being confined Thistaken in thought to discover the fair disturbance and ought to b e improved model of energy by assessment with the real arrangement of investigational information. Manickam et. al. (2019) The vortex tube by Ranque and Hirsch is a basic mechanical gear that allows isolating hot air and cold air coming from compacted air which is acting digressively to the body of the VT and going into the vortexchamber(a re gion in which the packed wind stream coming from the air) and they, for the most part.Matveev et. al. (2019**)** mathematically examination had been done and the hypothesis that comes before an analyst is that by expanding the size of VT with the cyclonic-type extension of vortex chambers. The CFD programming STAR-CCM + were used to investigate a sort counter-stream VT working with air as a functioning liquid.

III.METHODOLOGY

In this process generic design of vortex tube is modelled using CAD package and analyzed using ANSYS CFX. On that basis new component drawing is made and comparison of old and new design are done using ANSYS CFX.The CFD analysis involves 3 different stages which are preprocessing, solution and post processing. These steps are discussed below

- **CAD Modelling**

The CAD model of vortex tube generator is developed in Creo design software. The dimensions are taken from the literature. The dimensions of vortex tube are shown in table 1.1 below. The creo design software is parametric 3D modelling design software developed by PTC. The vortex tube design is developed using sketch, extrude and shell tool.

Table 1.1: Dimensions of Vortex Tube

Parameter	**Value**
Diameter of vortex tube (D)	.019 m
Diameter of cold end (d)	.007 m
Length of vortex tube (L)	.090 m
Semi cone angle (α)	25^0

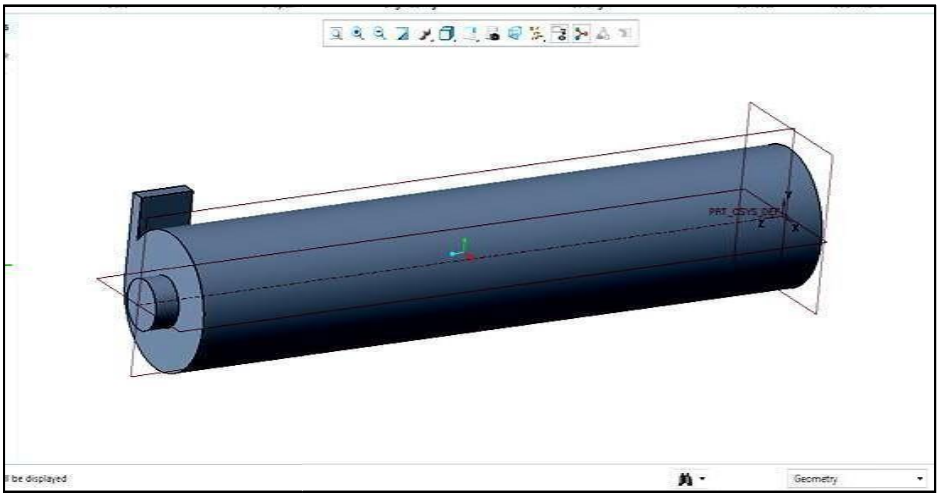


Figure1. CAD design of vortex tube

The developed CAD design of vortex tube is shown in figure 1.2 above. The model is applied with shell tool and convertedinto Para solid file format. The parasolid file format makes it compatible to open in other simulation package like ANSYS.

Table 1.2: Different dimensions of vortex tube by varying length and diameter

Design Type	Length (mm)	Diameter (mm)
D1	90	19
D2	100	19
D3	110	19
D4	90	18
D5	90	20

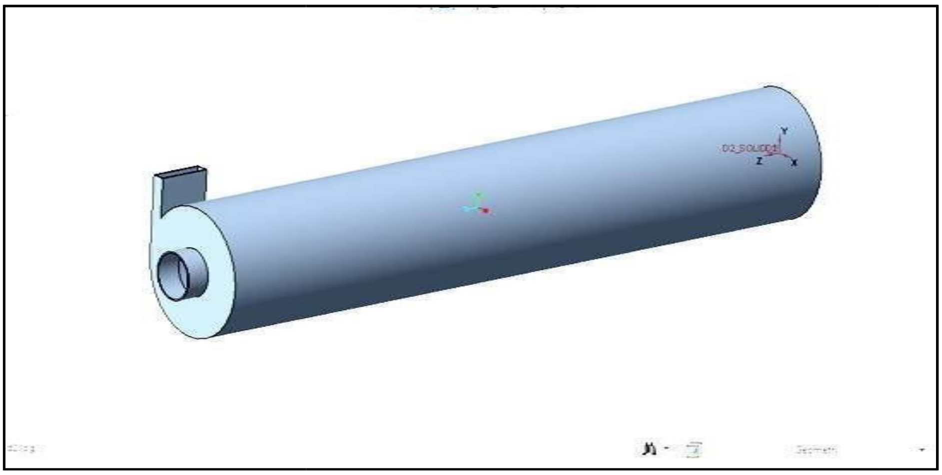


Figure 2. CAD design of vortex tube “d2”

The designs of vortex tube by varying diameter and length are presented in figures. These designs are then converted in Para solid file format to get it imported (compatible) in ANSYS simulation software.

- **Importing CAD model in ANSYS**

The CAD model of vortex tube in Para solid file format is imported in ANSYS design modeler. Here it is checked for geometric errors like hard edges, patches etc. The imported model of vortex tube is shown in figure below.

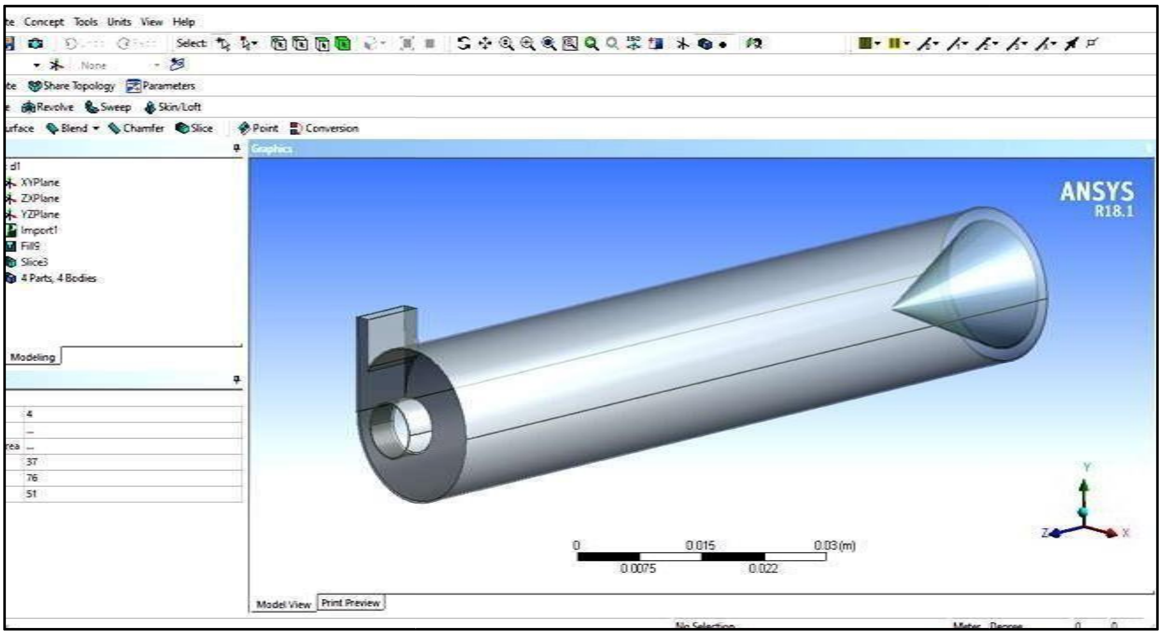


Figure 3. Imported CAD design of vortex tube in ANSYS design modeler

The fill tool is used to fill the cavity inside vortex tube. This volume will later be defined as fluid domain. The slice too l is used to cut the end section which is later suppressed. Similar operations are performed with other designs of vortex tube i.e. “d1”, “d2”, “d3”, “d4” and “d5”.

- **Meshing model in ANSYS**

The model of vortex tube is meshed using tetrahedral elements with fine sizing and curvature effects. The relevance center is set to fine and transition is set to slow with 0.77, the growth rate is set to 1.2 and maximum layers are set to 5. The number of elements generated is 444185 and number of nodes generated is 87829.

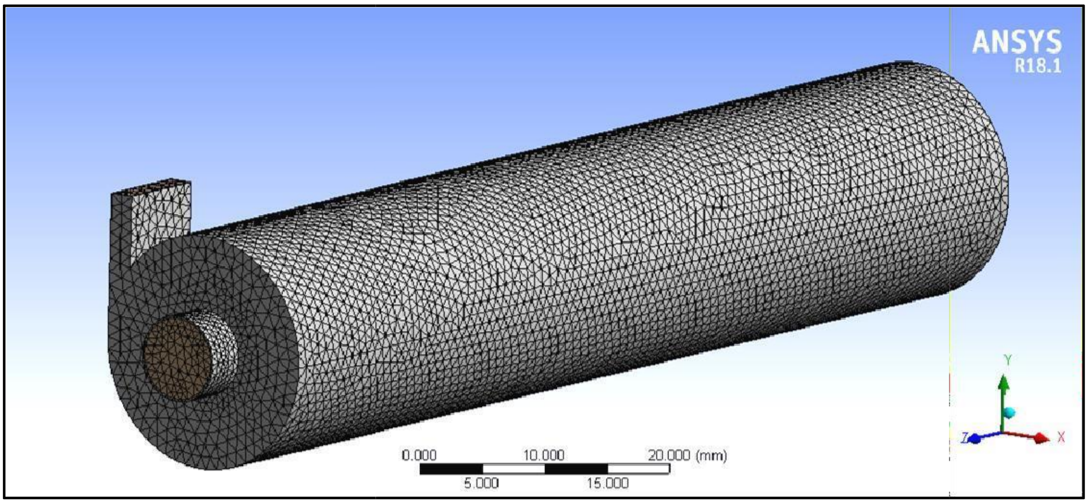


Figure 4. Meshed model of vortex tube

Loads and Boundary Conditions

The 1st step towards applying loads and boundary condition is setting up of fluid domain. The fluid material considered for the analysis is air ideal gas and reference pressure is set to 1 atm. Standard k epsilon turbulence model is set. The fluid domain is shown in figure below.

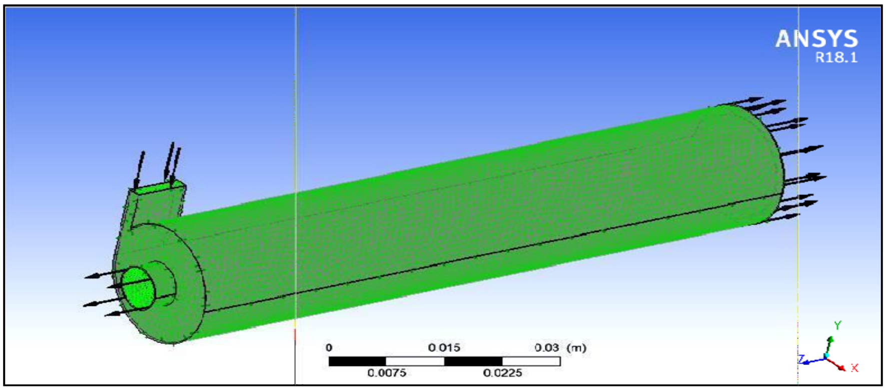


Figure 5. Fluid domain definition

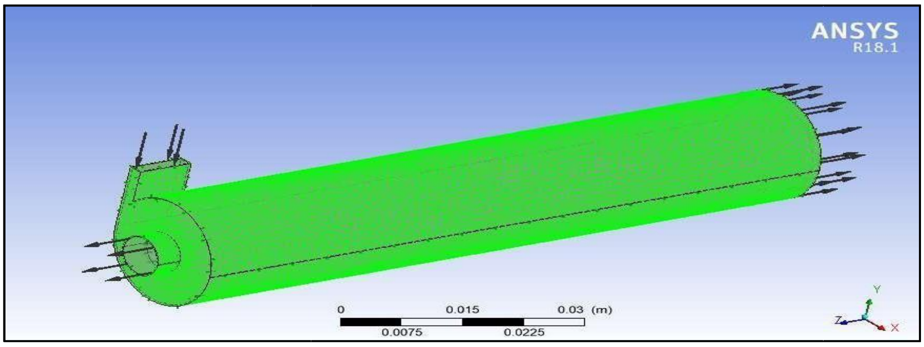


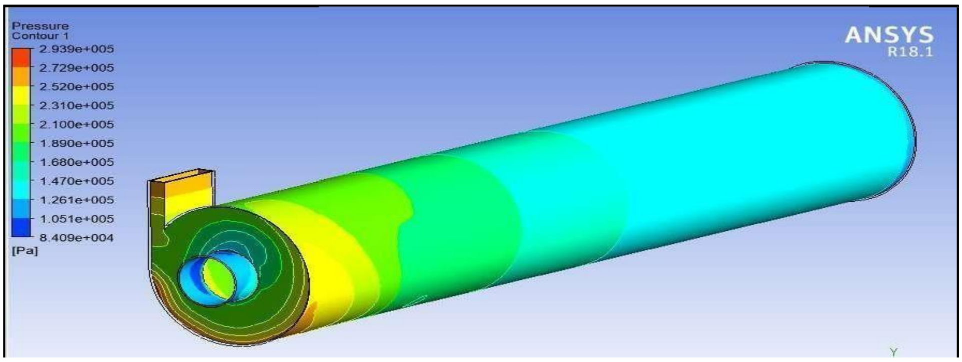
Figure 6. Solid domain definition

The outer solid domain is defined using steel material which is shown in figure above. The air inlet boundary condition is defined as show in figure 4.10 below. The total pressure of 5 bar is defined at the inlet boundary condition with total temperature of 303K. The turbulent intensity is set to 5%.

IV. RESULTS AND DISCUSSION

Simulation results of D1

The CFD simulation of D1 design is conducted to determine pressure and temperature profile. The pressure profile plot along fluid solid interface is shown in figure below. The pressure plot shows lower value at the cold air outlet temperature boundary and higher at the hot air exit surface. The pressure at the



hot air outlet is nearly 126100Pa

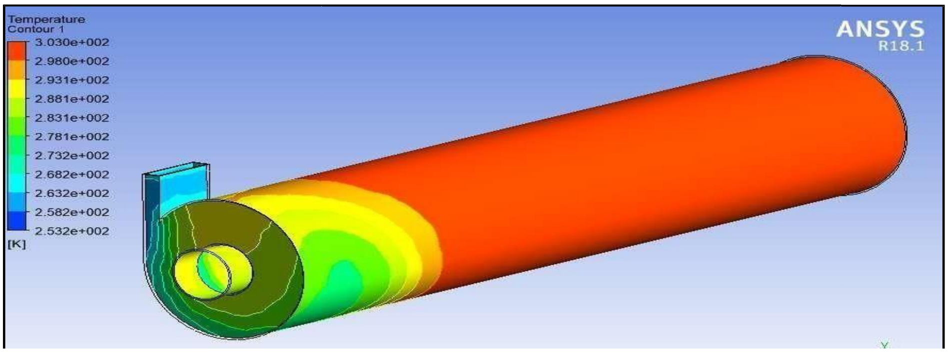


Figure 7. Temperature plot on inner face of vortex tube

The temperature plot across vortex tube is shown in figure above. The plot shows higher magnitude of temperature at the mid- section and near the hot air outlet boundary which is shown in red color. The temperature at the region is nearly 303K. The temperature towards the cold exit region is nearly 293K as can be seen in yellow colored region.

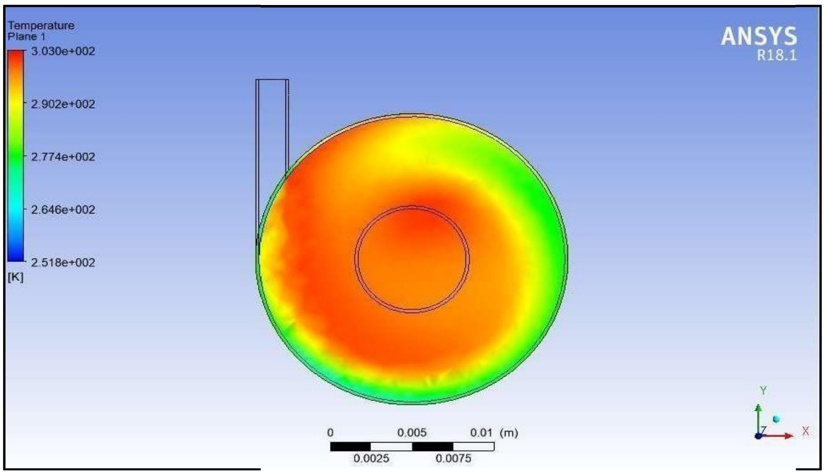
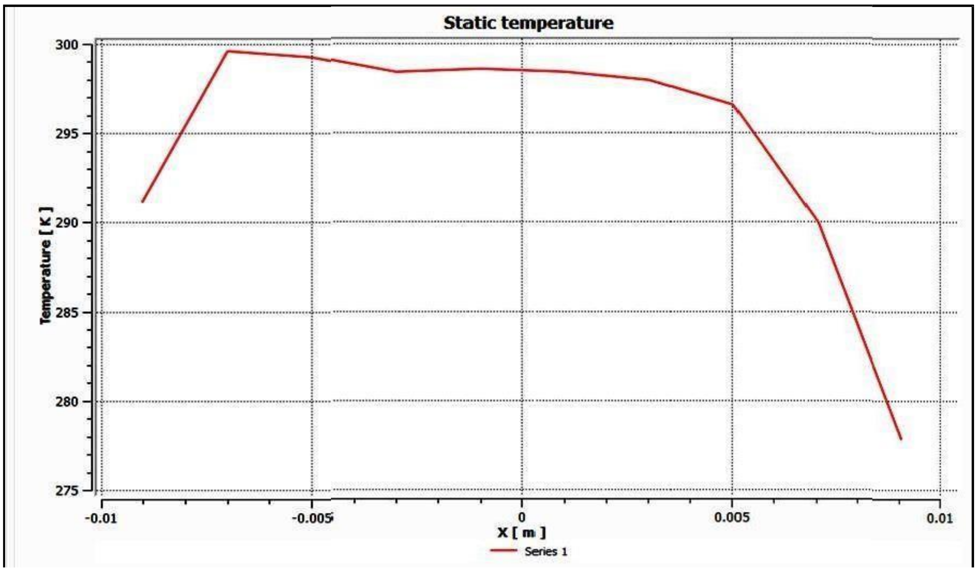


Figure 8. Temperature plot across plane



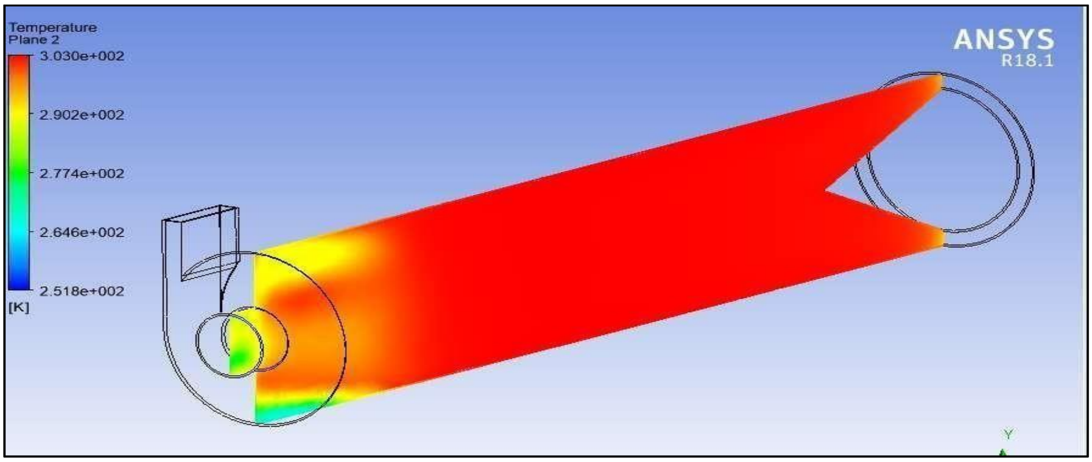


Figure 10. Temperature plot across longitudinal plane

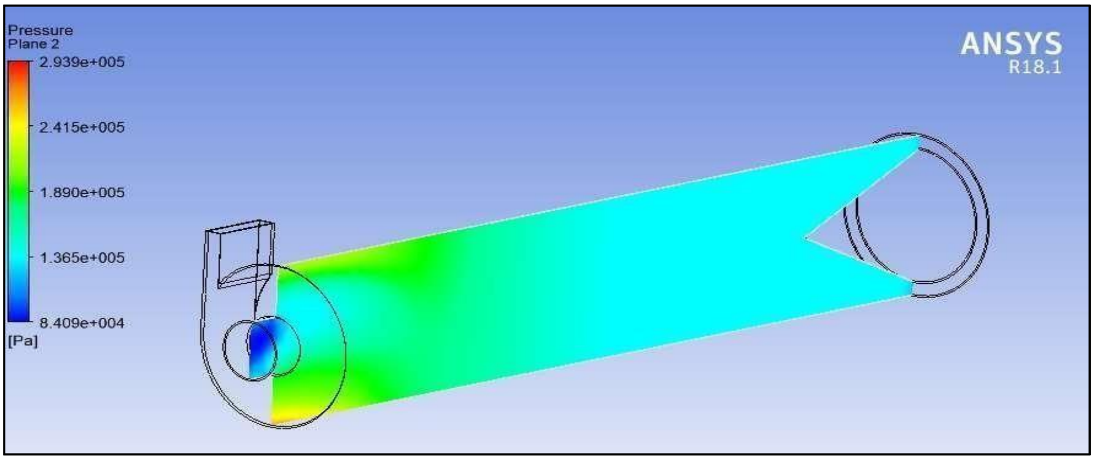


Figure 11. Pressure plot along longitudinal plane

- **Assumption**

The material of the vortex tube is assumed to be insulated. Thermal conductivity of the working fluid is assumed to be constant. The flow emanating from inlets for all cases are maintained constant as in the journal papers. Temperature separati on refers to the total temperature difference between inlet and cold end.

Table 4.1 Temperature Response of vortex tube on various material

S.No.	**Material**	**Temperature**			
		D1	**D2**	**D3**	**D4**
1.	Mild steel	305	306.7	305.45	306.5
2.	Brass	305	306.7	306.4	306.5
3.	Aluminum	305	306.7	306.4	306.5

V. CONCLUSION

The temperature is similar at most of the zones of the vortex tube as shown in red colored region. The temperature at the cold air exit region is nearly 290K which is shown in dark and light orange colour. The temperature across the longitudinal plane. The temperature reduces near the boundary surface of cold air outlet region which is shown in dark green colour. The minimum temperature observed is 270.2K.The temperature at the cold air exit region is nearly 291.2K which is shown in dark and light orange color. The temperature reduces near the boundary surface of cold air outlet region which is shown in dark green color. The minimum temperature observed is 272KThe pressure distribution across the longitudinal plane shows lower pressure at the cold air exit region with a magnitude of nearly 84600Pa and pressure is higher near the hot air exit of the vortex generator. The CFD simulation of D4 design is conducted to determine pressure and temperature profile. The pressure profile plot along fluid solid interface.The pressure plot shows lower value at the cold air outlet temperature boundary and is higher at the inlet with magnitude of nearly 277300Pa. it shows that the proposed vortex tube analysis has optimize with the temperature and pressure analysis.

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