A Study of Thermal Performance Testing for Annular Vortex Tube with reviews.

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Abstract : Vortex tube is the device which gives the hot and cold air at its both ends by reinforcing the pressurized air with proper quantity. This is one of the best example of temperature change due to flow and pressure. The arrangement of different sections allows the temperature variation on both ends. Also the flows which cause this change need to be studied well to understand the change in temperature.

There are several ways to check thermal performance of the Vortex tube. Available studies focuses on the flow and thermal performance. It is also found that some of the studies are also focusing on exergy analysis. The flow characteristics are also important and it must be studied to understand the effect of flow on the temperature change.

In this paper the several studies available on vortex tube and the thermal performance testing methods are studied. Conclusion is drawn on the study and further suggestions have given for the improvement in the thermal performance and the flow.

IndexTerms **- Vortex Tube, Exergy Analysis, Flow Characteristics, Thermal Performance.**

I. Introduction to Vortex Tube

Vortex Tubes are an effective, low cost solution to a wide variety of industrial spot cooling and process cooling needs. With no moving parts, and no refrigerants, the Vortex Tube spins compressed air to separate the air into cold and hot air streams. Thermal separation of flow is the key working of vortex tube. Entire study on tube will gives the different aspects of temperature separation. Figure 1.1 shows the general schematic diagram of vortex tube.

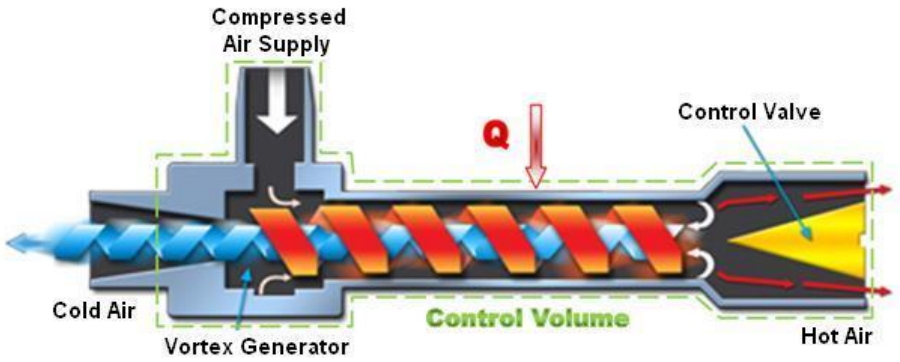

Fig. 1.1: Schematic diagram of Vortex Tube. [16]

Vortex tube consists of pipe of different diameter sections with air inlet, vortex generator, control valve etc. Each section has its own working importance. When the pressurized air is supplied from the inlet which is further entered into the vortex generator section where the swirling takes place in the air flow. Due to the swirling and control valve provided at the end the thermal separation occurs and we get the hot and cold air at both ends.

Advantages and Disadvantages

- No leakage problem in case of refrigeration.
- Initial cost and working expenses are very low as compared with others.
- Efficiency is low as compared with other available methods.
- Limited capacity vortex tubes are only available.

II. Literature Reviews

Yunpeng Xue, Maziar Arjomandi and Richard Kelso: This is one of the important experimental research which was done to know the separation of temperature. For that purpose flow properties are studied well. Swirl velocity, Radial Velocity, Axial Velocity, Turbulence intensity and pressure variation along a vortex tube are studied. The findings of entire experiment are explained well to understand how the separation of temperature is done.

But the temperature separation is again not cleare as they have focused on flow properties. Since this study can help to understand the thermal separation, but enable to explain thermal separation clearly. Kinetic energy is used in irrotational vortex for thermal separation while it slightly changes the exergy density inside the vortex. [1]

Sarath Sasi, Sreejith M: In this study the author proposed methods to get maximum efficiency in minimum cost of the vortex tube. Eco friendly system is be developed for this as per the suggestion in study. Several changes were made like nozzle number, vortex tube material, different cone angles, different mass fraction etc. With these changes the behavior of the tube is checked and accordingly conclusions were made. Major importance is given for the environment and nature. This study helps to understand the eco friendly research in vortex tube era. [2]

Seyed Ehsan Rafiee and M. M. Sadeghiazad: The numerical investigations is represented on the impacts of length of main (hot) tube (95 to 125 mm) and on boundary condition type with thermal capability (heating and cooling) of the vortex tube and the heat and mass transfer between the cold and hot vortex cores inside a Ranque-Hilsch vortex tube applying the 3D CFD models. The cooling and heating capabilities increase severely with an increase in the main tube length upto 115mm (optimum value) and beyond L=115mm the thermal effectiveness of vortex tube decreases. The results have been compared to the experimental values with good agreement (less than 7 %). [3]

Nader POURMAHMOUD: In his study the CFD analysis of vortex tube is carried out to understand the effect of operating pressure. Standard k-ε turbulence model is used to derive the Numerical results of compressible and turbulent flows, where throughout the vortex tube was taken as a computational domain. The main objective of study is to focus on the importance of identifying the suitable inlet gas pressure corresponds to used vortex tube geometry. Achieving a highly swirling flow and consequently maximum cold temperature difference were the key parameters of judgment. The results revealed that these acceptable conditions of machine performance can be provided when the inlet operating pressure is appropriate both to mechanical structure of machine and physical properties of working fluid. The stagnation point location in the axial distance of vortex tube and Mach number contours in the vortex chamber as additional information are extracted from flow filed; such that interpretation of shock wave formation regions may be accounted as significant features of investigation. Finally, some results of the CFD models are validated by the available experimental data. [4]

Mohammad O. Hamdan, Ahmed Alawar, Emad Elnajjar & Waseem Siddique: Their study is based on vortex tube performance where the results obtained by them are giving confirm step towards the vortex tube thermal separation. As per their study the inlet pressure and cold fraction are the most important parameters which affect the performance of vortex tube. With the experimental results they have also shown that if the number of nozzles at the inlet increases then the performance of the vortex tube increase, simultaneously the energy separation increases. [5]

T. Dutta, K. P. Sinhamahapatra, and S. S. Bandyopadhyay: Study of the energy separation phenomenon in vortex tube (VT) at cryogenic temperature (temperature range below 123 K) has become important because of the potential application of VT as in-flight air separator in air breathing propulsion. In the study the CFD analysis of vortex tube is done with gaseous air at cryogenic temperature. With this analysis it is found that the separation of temperature is less at a cryogenic temperature as compared with the normal atmospheric temperature. Transfer of tangential shear work from inner to outer layer is found more responsible for temperature separation. [6]

Waraporn Rattanongphisat and Krairin Thungthong: A study shows a thermoelectric module is used to extract heat from the hot tube surface and then release it to environment. i.e. temperature difference is used to generate power by the thermoelectric generator as thermal energy harvester. A test rig is designed and constructed, in the laboratory, for the experiment on the vortex cooling system incorporating the thermoelectric module. Test parameters are the cold fraction from 0 to 1 and an inlet air pressure of 1.5 bars. The results show that the cooling capacity and efficiency increase when the thermoelectric module is used to extract heat from the hot tube surface of the vortex tube and electricity is generated as by product. The cooling capacity and efficiency of the vortex tube is increased by 4.3 % and 9.6 % respectively. [7]

Ramesh ganugapenta1, G.R Selokar2, P Venkat Rathnam: Delrin material is used to design and manufacturing of vortex tube in order to improve the performance of the vortex tube. Study aimed to obtain suitable orifice diameter and inlet pressure to get cooling and heating effect. Also validation of the best diameter for the chosen performance measures of COP is done. [8]

Sayali Darekar, Makarand Date, Shubham Chaudhari, Mangesh Dudhare, V.S. Bagade have given the review on the experimental analysis of vortex tube. They explained that the performance of vortex tube is dependent on two basic parameters, first is the working parameter such as inlet pressure of compressed air,

and the other one is geometric parameters such as number of nozzles , diameter of nozzle, cone valve angle, length of hot side tube, cold orifice diameter, and as well as material of vortex tube. [9]

III. Outcomes from study

- Performance of vortex tube can be increased with the number of nozzles and its diameter, cone valve angle, length of hot side tube, cold orifice diameter, and as well as material of vortex tube. [9]
- CFD Analysis of vortex tube can explain flow characteristics inside the tube.
- Separation of temperature is done by flow and inlet pressure.
- Vortex tube is the eco friendly device which gives hot and cold air at both ends. [7]
- More focus is needed on the flow of air through the vortex tube.
- Experimental investigations are able to prove the performance improvement of vortex tube.
- Thermal performance can be improved with the length of the tube.

IV. Aims and Objectives

- To understand the flow characteristics of air inside the tube.
- To understand the temperature separation inside the tube at both end.
- Study of vortex tube performance and efficiency improvement.
- Methods of improving the performance and efficiency.

V. Thermal Performance of Vortex Tube

Method to Find Thermal Performance

Compressed air is admitted to the vortex tube through in the nozzle the air acquires high velocity and enters the chamber tangentially where it forms a vortex. This vortex is formed because of the particular shape of the chamber. The vortex travels through the hot side of the tube through the diaphragm. Part of this air flows back towards the diaphragm. It then leaves the tube through the diaphragm and the cold end. The hot air passes through the valve. By adjusting the valve opening the quantity of cold air and the temperature drop can be varied. The maximum drop is obtained for a particular opening of the valve. A decrease in temperature drop will result by reducing the valve opening below this opening.

Practical method was the only method available to find the thermal performance of the vortex tube. But now days the Computational Fluid Dynamics (CFD) is the method made available to find the thermal performance of the vortex tube.

CFD Method

It is the method from which the actual flow patterns in the form of velocity, pressure, temperature, and turbulence etc. change can be obtained without performing actual experimentation.

In this method FVM technique is utilized for obtaining results. ANSYS Fluent is one of the tools which is mostly used to solve fluid flow problem. In this study the implementation of this tool is proposed to obtain the air flow pattern through vortex tube.

Working Principle

It is mentioned in this study the CFD works on FVM method to solve fluid flow problems. Boundary conditions are specified in terms of inlet velocity, pressure outlet, and temperature of flowing air. Air properties are also considered. Meshing process is carried out for object to be analyzed. And lastly fluid flow problem solved with number of iterations.

VI. Applications

There are several applications of vortex tube specially in food industry, cold storage, Air dryers

Conclusion

From above study it is clear that the inlet pressure and flow characteristics of flowing air are the main responsible for the thermal separation. Velocity distribution along a vortex tube is changes with sections. Further more study is required to understand the nature of air flow from vortex tube.

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