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Analysis: Design Optimization of Vortex Tube

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Abstract: Vortex tube is a device which uses air as refrigerating fluid, since air is abundantly available in nature hence vortex tubes proves to be inexpensive and un hazardous to nature. The vortex tube is a structurally simple device with no moving parts that is capable of separating a high pressure flow into two lower pressure flows with different energies, usually manifested as a difference in temperatures. Different design approaches are used to manufacture the vortex tube. Literature review reveals investigations to understand the heat transfer characteristics in a vortex tube with respect to various parameters like cross section area of cold and hot end, nozzle area of inlet compressed air, cold orifice area, hot end area of the tube, and L/D ratio. As such there is no theory so perfect, which gives the satisfactory explanation of the vortex tube phenomenon as explained by various researchers. Therefore, it was thought to perform experimentation this paper review about the different design approaches and analysis of them.

Keywords: Vortex tube, Design, Optimization, Temperature, Air-conditioning.

I. INTRODUCTION

The vortex tube is a device which generates separated flows of cold and hot gases from a single compressed gas source. The vortex tube was invented quite by accident in 1933 by George Ranque and later developed by Hilsch (1947).In memory of their contribution the Vortex tube is also known as Ranque-Hilsch vortex tube (RHVT).It contains the parts: inlet nozzle, vortex chamber, cold-end orifice, hot-end control valve and tube.

Vortex tube is a mechanical device that separates a compressed gas into hot and cold streams. The air emerging from the "hot" end can reach temperatures of 200 °C (392 °F), and the air emerging from the "cold end" can reach −50 °C (−58 °F).[1] It has no moving parts. Pressurized gas is injected tangentially into a swirl chamber and accelerated to a high rate of rotation. Due to the conical nozzle at the end of the tube, only the outer shell of the compressed gas is allowed to escape at that end. The remainder of the gas is forced to return in an inner vortex of reduced diameter within the outer vortex.

A vortex flow is generated inside the chamber and air travels in spiral like motion along the periphery of the hot side.

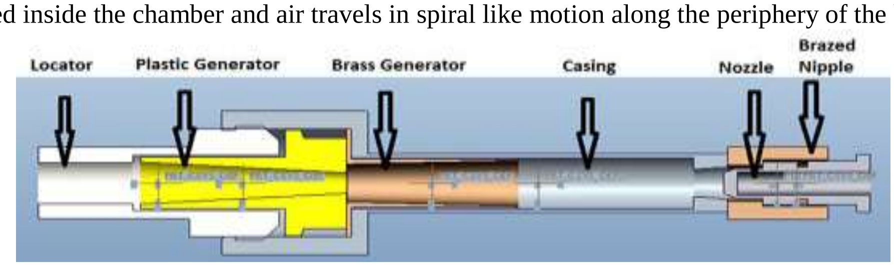

Fig: Vortex Tube

The working principle of the vortex tube is as shown in Fig. Compressible fluid is tangentially introduced into the vortex tube through the nozzles, due to the cylindrical structure of the tube and depending on its inlet pressure and speed, leads a circular movement inside the vortex tube at high speeds. A pressure difference between the tube walls is lower than the speed at the tube center, because of the effects of wall friction. As a result, fluid in the center region transfers energy to the fluid at the tube wall. The cooled fluid leaves the tube by moving against the main flow direction after a stagnation point, whereas the heated fluid leaves the tube in the main direction. The RHVT is widely used for both cooling and heating purpose. This flow is restricted by the valve. When the pressure of the air near valve is made more than outside by partly closing the valve, a reversed axial flow through the core of the hot side starts from high-pressure region to low pressure region. As the vortex moves along the tube, a temperature separation is formed. Hot air moves along the tube periphery, and cold air is in motion in the inner core.

The hot air is then allowed to exit through the cone valve at the far end of the tube, while the cold air outlet is next to the inlet plane. During this process, heat transfer takes place between reversed stream and forward stream. Therefore, air stream through the core gets cooled below the inlet temperature of the air in the vortex tube, while airstream in forward direction gets heated up. Colder, low pressure as leaves via an orifice near the center line adjacent to the plane of the nozzles and warmer, low pressure as leaves near the periphery at the end of the tube opposite the nozzles. The principle is said to have been discovered by Rudolf Hilsch [5], German physicist in 1945, took further the challenge to complete the obscured work of George Ranque [5], who first invented the vortex in 1928 but failed to exploit its usage commercially. Using the tube within solution to reduce energy loss to surroundings gave a higher temperature separation in the tube than that without insulation around 2-30C for the cold tube and 2-50C for the hot tub.

Designing criteria of the vortex tube is based upon the following condition:
1. Ambient pressure (Pa)
2. Inlet pressure (Pi)
3. Inlet temperature (Ti)
4. Cooling temperature (Tc)
5. Temperature of hot body (Th)

Considering the above conditions with respect to the various application of the vortex tube, the following designing parameters need to be selected:
1. Diameter of hot tube (D)
2. Length of hot tube (L)
3. Cold orifice diameter (dc)
4. Area at the hot end

II. LITERATURE SURVEY

Akash S. Bidwaik et al. [1] conclude that for increased in number of tangential nozzle on vortex generators the ratio of L/D ratio should be greater than 11.5.The generator with orifice diameter7mm provide the best result for double inlet vortex tube.

G. Suresh Kumar et al [2] concluded that all the parameters considered are found to have significant effect on the response statistically. For optimum hot outlet temperature, the settings of the parameters are: **L -** 180 mm; **Dt –** 14 mm **;Dn**– 17 mm; **Do** – 8 mm; and **P –** 3 Kgf/cm2. The results of this work are useful to motivate the industry to use the vortex tube for suitable heating applications.

Sunil Chamoli et al [3], shows that the optimal parameters have been designed to maximize the heat transfer and minimize the pressure drop by Taguchi method. The selected parameters for performance prediction of V down perforated baffle roughened rectangular channel are relative roughness pitch (P/e), relative roughness height (e/H), open area ratio(β) and Reynolds number(Re).The conclusion is 1. The most important parameter with the aspect of heat transfer is Reynolds number, as the Reynolds number shows the contribution ratio of the order of 73.97%. Thus heat transfer can be improved by controlled change of flow Reynolds number.2. IftheTaguchioptimizationmethodisconcernedonlywithrespecttofrictionfactor, among the effective parameters on system performance, e/H and Re are understood to be the most effective ones. 3. The analysis of variance ANOVA was performed to determine the variance of each control factor on the overall results and it was found that the most important parameter for variance is Reynolds number and relative roughness height co- responding to Nusselt number and friction factor, respectively. 4. The results show that in order to optimize the geometrical and flow parameters of V down perforated baffle roughened rectangular channel for heat transfer and friction factor.

Kiran Devadeetal[4] , conclude that, The results show increase in cold mass fraction as well as cold end temperature. The overall change in cold end temperature drop was 63% and the COP of the converging tube as compared to straight divergent tube increased by 102%. For conical valve angle of 450 air supply pressure of 5 bars and cold orifice diameter as 7 mm the lowest temperature observed was 50C producing cold mass fraction of about 0.9. The result is that the converging type of vortex tube has proved to be promising as far as the optimization of cold mass fraction and lower cold end temperatures are considered. It has satisfactorily produced lower temperature of about 50C and cold mass fractions of the order of 0.9 with COP as high as 0.202. The adiabatic efficiency of the tube is on higher side and is 208%. But small deviation of 0.39 is observed in theoretical and actual COP of the tube. The same can be improved and brought nearer to the theoretical value.

CONCLUSION

Designing criteria of the vortex tube is based upon the following condition: 1. Ambient pressure (Pa), 2. Inlet pressure (Pi), 3. Inlet temperature (Ti), 4.Cooling temperature (Tc), 5.Temperature of hot body (Th).Considering the above conditions with respect to the various application of the vortex tube, the following designing parameters need to be selected: 1. Diameter of hot tube (D), 2. Length of hot tube (L), 3. Cold orifice diameter (dc), 4. Area at the hot end. This paper provides the designing criteria of the vortex tube.

REFERENCE

[1] Akash S. Bidwaik, SumitMukundDhavale "To Study the Effects of Design Parameters on Vortex Tube with CFD Analysis", IJERT, Vol. 4 Issue 10, October-2015.

[2] G. Suresh Kumar, G. Padmanabhan, B. DattatreyaSarma, "Optimizing the Temperature of Hot outlet Air of Vortex Tube using Taguchi Method", 12th GLOBAL CONGRESS ON MANUFACTURING AND MANAGEMENT, GCMM 2014, Procedia Engineering 97 (2014) 828 – 836

[3] Sunil Chamoli, "A Taguchi approach for optimization of flow and geometrical parameters in a rectangular channel roughened with V down perforated baffles", JCSTE, Case Studies in Thermal Engineering 5 (2015)59–69

[4] Kiran Devade, "Effect of cold orifice diameter and geometry of hot end valves on performance of converging type Ranque Hilsch vortex tube", 4th International Conference on Advances in Energy Research 2013, ICAER 2013pg642-653.

[5] Ranque GJ (1933) Experiments on expansion in a vortex with simultaneous exhaust of hot air and cold air. J Phys Radium (Paris) 4:112-114, June. Also translated as General Electric Co., Schenectady Works Library 1947; T.F 32941. Hilsch R (1947) the use of expansion of gases in a centrifugal field as cooling process. Rev Sciinstrum 18(2):108-113.

