Impact Factor Value 4.046 e-ISSN: 2456-3463
National Conference on Quality Up-gradation in Engineering, Science and Technology (NC-QUEST018)
Organized by College of Engineering and Technology, Dhanamgaon Rly-444709
International Journal of Innovations in Engineering and Science, Vol. 3, No.6, 2018
www.ijies.net

Design and Manufacturing Vortex Tube

Akash Welukar[1] Rahul asode[2] Karan badgaiyaa[3] Devanshu raut[4]

Guided by

[1]Assistant Professor, Professor A. T. Bathe
Mechanical Department, DES'SCOET, Dhamangaon Rly, Dist: Amravati, 444709 Maharashtra, India

Abstract –*.Now-a-days, the first and foremost important quality of any research or development is its eco-friendly nature. As we know environment safety has become an important aspect of the industries and people in common. Vortex tube is also known as non-conventional cooling device that will produce cold air and hot air when we passed compressed air from compressor without causing any harm to the nature. In vortex tube, when a compressed air from compressor is tangentially passed into vortex chamber a free and forced vortex flow will be generated which will be divide into two air streams i.e., one has lower temperature than inlet temperature and other one has higher temperature than inlet temperature. It can be used for any type of spot cooling application. In this research an attempt is made to fabricate and test a simple vortex tube. The effect of change in length and diameter of vortex tube i.e., (L/D) ratio is investigated and presented in this project*

Keywords: *Vortex tube, compressed air, hot air, cold air, nozzle*.

INTRODUCTION

The Vortex tube, also known as the Ranque-Hilsch vortex tube, is a mechanical device operating as a refrigerating or cooling machine without any moving parts, by separating a compressed air/gas stream into a low temperature region and a high one. Such a separation of the flow into regions of low and high temperature is referred to as the temperature (or energy) separation effect. Generally, the vortex tube can be classified into two types. One is the counter flow type (often referred to as standard type) and another is parallel or uni-flow type. The air emerging from the "hot" end can reach temperatures of 200 °C, and the air emerging from the "cold end" can reach - 50 °C. It contains the following parts: one or more inlet nozzles, a vortex chamber, a cold-end orifice, a hot-end control valve and a tube. When high-pressure gas is tangentially injected into the vortex chamber via the inlet nozzles, a swirling flow is created inside the vortex chamber. When the gas swirls to the centre of the chamber, it is expanded and cooled. In the vortex chamber, part of the gas swirls to the hot end, and another part exist via the cold exhaust directly. Parts of the gas in the vortex tube reverse for axial component of the velocity and move from hot end to the cold end. At the hot exhaust, the gas escapes with a higher temperature, while at the cold exhaust, the gas has a lower temperature compared to the inlet temperature.

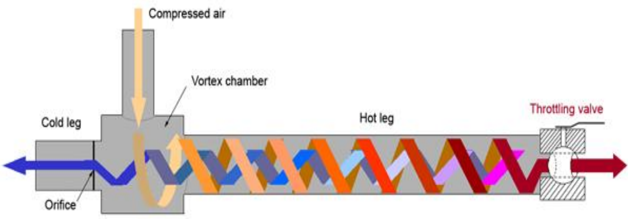

Figure 1: Vortex tube

Vortex tube was invented by French physicist G.J. Ranque in 1931. But due to its inefficiency the patent and idea was rejected and it was highly unpopular. Later in 1947, German engineer R Hilsch modified the design. Henceforth, there had been a lot of research on the energy separation process of the vortex tube but there was no concordance. Vortex tube is a simple mechanical device used for separating a compressed fluid generally air into streams of hot and cold air respectively. Air is commonly used fluid in the vortex tube but it can employ other gases as well. In this analysis air is considered as working fluid. Inlet nozzles are located near the cold end side while hot end is located from the inlet nozzles. An orifice plate is located near the cold end to restrict the flow towards hot direction only. At the hot end of the tube the conical valve is provided to limit the amount of air to be sent to the atmosphere. This conical valve is adjustable. Compressed air is injected tangentially into tube through the nozzles and air is subjected to whirling action creating free vortex due to the periphery of the tube. Since an orifice plate is provided near the cold side of the tube and concentric to hot tube, air is forced to move towards hot side of the tube which partly escapes due to the conical valve while remaining air strikes the valve and returns towards the cold end in linear way. During this process, the central stream loses its energy to the peripheral stream.

. A percentage of the hot, high-speed air is permitted to exit at the control valve. The remainder of the (now slower) air stream is forced to counter flow up through the center of the high-speed air stream, giving up heat, through the center of the generation chamber finally exiting through the opposite end as extremely cold air. For the performance analysis of this kind of vortex tube is being made on the basis of some series of different-different mechanical, physical and constructional features and the performance of tube depends upon:

(a) Air parameter

(b) Tube parameter

LITERATURE REVIEW

- **Avinash Patil et al:-** This investigation to understand the heat transfer properties in vortex tube with respect to number of parameters i.e. cross section area of hot and cold end, nozzle area of inlet compressed air, cold orifice area, hot end area of the tube, and L/D ratio. There are two design features associated with a vortex tube which is maximum temperature drop vortex tube design for producing small quantity of air with very low temperatures and maximum cooling effect vortex tube design to produce air at large quantity with different temperatures. Vortex tube can be used for any type of spot cooling or spot heating application. [1]
- **Chetan D Bhimate et al: -** This investigation the counter flow vortex tube has been designed, manufactured and tested. The vortex tube is non-conventional cooling device which operates as a refrigerating unit without effecting environment. There are two parameters which are controls the working of pressure tube. First is inlet pressure of compressor air & cold mass fraction. & geometric parameters & Second is material of vortex tube affect coefficient of performance (COP). PVC material is used for manufacturing of the vortex tube as which has lower thermal conductivity than metals & less fluid friction losses. The temperature drop increases with increase in inlet pressure. [2]
- **Deepak Patel et al: -** Investigate experimentally coefficient of performance by using compressor. It is used for industrial spot cooling and process cooling. The commonly used cooling systems use the gas and liquid. It include various aspects for achieving maximum C.O.P. the experiment is carried out with a series of different physical, thermal and mechanical conditions and analysis of difference in temperature, cooling and heating effect, and C.O.P. with different working conditions and constructional features. [3]
- **H. Thilakan et al: -** The experimental was started from the design and fabrication stage of vortex tube refrigerator. Cold orifice diameter is important part in performance Vortex tube. This paper describes the experimental study on vortex tube refrigerator with conical valve angle at the hot side and the effect of cold orifice diameter at cold side on the performance of vortex tube refrigerator. The diameter of orifice influences the expansion that take place in vortex chamber. Temperature also changes at opening of stop valve. When it opens at few variations then air allow to escape at hot end reduces and maximum temperature difference increases. If opening is increases air escaped from pipe easily which is turn decreases maximum temperature difference is obtained. [4]

DESIGN PARAMETER AND ANALYSIS

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)

Present design is purely based on empirical relation supported with standard key geometry such as cold orifice diameter (dc= 5 mm, 6 mm, 7 mm). The system is design for supply pressure more than 4 bars. dc

The cold orifice diameter dc is selected as 6 mm for better cooling effect. Therefore tube diameter D = 12 mm.

Design parameter: L/D = 1.66mm

∴ Length of the tube L = 1600mm

The design parameters are decided for optimum results on basis of literature survey. Investigation was done by using vortex generator with 8 inlet tangential nozzles and also based on different orifice diameters such as,

dc = 5mm, 6mm, 7mm

FORMULAE USED

- Area = Π/4*D2
- Discharge (q) =A*V
- Mass flow rate (m) = q* ρ
- Cooling effect (q) = mCpΔT
- Actual COP = actual cooling effect in vortex tube/ Work done by air compressor = Q/W
- Temperature difference (ΔT)
- Time for total number of revolutions (t)
- Total number of revolution of energy meter (n)
- Velocity(v) Designing criteria of the vortex tube is based upon the following condition:

The cold flow mass ratio (cold mass fraction) is the most important parameter used for Indicating the vortex tube performance of RHVT. The cold mass fraction is the ratio of mass of cold air that is released through the cold end of the tube to the total mass of the input compressed air. It is represented as follows:

DESIGN PROCEDURE

The main aim of this setup is the production of a Vortex path of air. Since the nozzle is tangential, air entering through it gets a swirling motion inside the cylinder. The air acquires a high velocity and travel towards the valve (in the end of the hot side) as a spiral vortex. When the swirling flow reaches the end, it is resisted by the partially opened valve. Due to the conversion of kinetic energy, the pressures of the air near the valve increases and a reversed axial flow through the low pressure case. By controlling the opening of the valve, the proportion of cold air and hot air and their temperatures can be varied. some of the restrictions followed were:- 1. For obtaining the maximum temperature difference at cold end, the ratio L/D should be maintained in the range of 30 ≤ L/D ≤ 60. hence, considering the length to be 113.03cm and diameter to be 2.05cm, we get the L/D ratio to be in the range. 2. Decreasing conical valve angle have positive effect on performance of vortex tube but not so much difference is observed in the temperature reduction. Therefore it is better to use conical valve with smaller angle in order to improve the performance of vortex tube. 3. The following schematics is followed

Fig: design of vortex tube

EXPERIMENTAL PROCEDURE

At first we run the compressor for 15 minutes to get stable pressure. Throughout our experiment we have maintained the input conditions constant. As we pass the pressurized air into the vortex chamber through the holes that are made at an angle i.e., tangentially then, in this chamber first air circulates and enter through the holes that are made in the hot side pipe and air moves towards the hot end where we have setup of control valve. As the air reaches near the control valve and when the pressure of the air becomes greater than the outside

CALCULATION

1) Density of air $\boldsymbol{\rho_a} = \mathbf{P_a/(RT_a)}$

$$= \frac{1.01325 \times 105}{287 \times 300} = \mathbf{1.176\ kg/m^3}$$

2) Flow rate $\mathbf{v_a = cd\ a\ (2gh_a)^{1/2}}$

$\mathbf{h_a = (h_w\ \rho_w)/\rho_a} = (8.4 \times 10^{-2} \times 10^3) / 1.176$

$= 71.428$ m of air

Therefore

$\mathbf{v_a} = 0.6 \times \{\pi \times (0.012)^2\}/4 \times [2 \times 9.81 \times 71.428]^{1/2}$

$= 2.539 \times 10^{-3}\ m^3/s$

Flow rate at NTP, $\mathbf{v_{ntp} = (va\ T_o)/T_a}$;

T_o = normal temperature=273 K

T_a= ambient temperature = 300K

$v_{ntp} = \{2.539 \times 10^{-3} \times 273\} / 300$

$= 2.275 \times 10^{-3}\ m^3/s$

3) Refrigeration effect $\mathbf{= \dot{m}\ Cp\ \Delta T}$

Where

$\dot{m}$= mass flow rate

$= 2.67 \times 10^{-3} \times 1.005 \times (300 - 297)$

$= 5.3667$ W

4) Work done $= \frac{3600}{E\ t} \times 2 \times 10^3$ W

Where

E= energy meter constant for compressor used

t = time taken for 2 seconds for the energy disc to rotate hence

Work done $= (3600/1000) \times (2/35.81) \times 10^3$

$= 201.06$ W

5) Coefficient of performance (COP)

= Refrigeration effect/ work done

$= 5.3667 / 201.06$

$= 0.026$

CONCLUSION

1. The results obtained by using PVC as the material provides similar outputs to that of the tests conducted by pioneer scientists such as Hilsch and Reynold.
2. By increasing the mass flow rate, the temperature gap increases and hence produces a high COP.
3. Mass flow rate can be adjusted by the valve position of the conical valve.

Firstly, we have a good understanding about the inner flow state after lots of research theoretically and established a reasonable explain about energy separation by analyzing the momentum of viscous liquid at different radius in the vortex chamber which will help other research on vortex tube easier and promote the development of vortex tube.

ACKNOWLEDGEMENT

Person who gave scientific guidance, participated in discussions, or shared unpublished result person who provided sample or equipment Assistants or students who helped do the work Technicians at user facilities or labs.

REFERENCE

[1] Piotr A. Domnski, David Yashar- "Performance of a Finned Tube Evaporator Optimized for Different Refrigerants and its Effects on System Efficiency". Elsevier journal (2009)

[2] S.S. Thipse, "Refrigeration & Air Conditioning" Jaico publishing house; 2007.

[3] Prof. P.S. Desai, "Refrigeration & Air Conditioning" Khanna publishers; 2004. [4]Ratnesh Sahu-"Comparative analysis of Mint Gas with refrigerant R-12 and R-134a". IJSER journal,2011

[4] Prof. U.S.P. Shet , Prof. T. Sundararajan and Prof. J.M . Mallikarjuna "Refrigeration Cycle" IIT Madras.

[5] C_U_Linderstrom-Lang. "The three-dimensional distributions of tangential velocity and total-temperature in vortex tubes" part1: Journal of Fluid of Mechanics. 1971, l45:161—187.

[6] T. Amitani; T. Adachi; T. A. Kato. Study on temperature separation in a large vortex tube. Japan Soc Mech Eng, 1983, 48: 877–884.

[7] R.T. Balmer. Pressure-Driven Ranque-Hilsch Temperature separation in liquids. ASME J Fluid Eng 110: 161–164

[8] Shu He; Yuting Wu; Chongfang Ma; Jian Guo, Yu Ding, Manchu GE. Experimental Study on the Length of Vortex Hot Tube Effect on the Performance of Vortex Tube Refrigeration Air Conditioning & Electric Power Machinery, 2005, 26(4):4_6.

[9] Shu He; Yuting Wu; Shu Jiang; Chongfang Ma; Manchu Ge. Effect of nozzles on energy separation performance of vortex tube. Journal of Chemical Industry and Engineering (China), 2005, 56(11):41-44.