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Fabrication and Capability Analysis of a Vortex Tube

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***Abstract*— *Vortex tube is a cooling device which generates cold air and hot air from a single source of compressed air without affecting the environment. When a high pressure air is tangentially injected into vortex chamber a strong vortex flow will be created which will be split into two air streams. It can be used for any type of spot cooling or heating application. In this present work fabrication of vortex tube has been done. Performance of vortex tube is evaluated by varying the orifice diameters ranging from 4mm-8mm, and varying the inlet pressures from 4bar-7bar.*

***Keywords*— *Vortextube,orifice, inlet pressure, tangential nozzle.*

I. Introduction

Conventional refrigeration systems are using Freon as refrigerant. As they are the main cause for depleting ozone layer, extensive research work is going on alternate refrigeration systems and alternate refrigerants.

Vortex tube (VT) is a device that generates cold and hot air stream from the source of compressed air. It contains the parts: inlet nozzle, vortex chamber, cold-end orifice, hot-end control valve and tube. Fig. 1 shows the construction of vortex tube. When high pressure gas is tangentially injected into the vortex chamber through the inlet nozzles, a swirling flow is created inside the vortex chamber. In the vortex chamber, part of the gas swirls to the hot end and another part exist through the cold end directly. Part of the gas in the vortex tube reverses for axial component of the velocity and move from the hot end to the cold end. At the hot end, the air escapes with higher temperature, while at the cold end, the air has lower temperature compared to that of the inlet temperature pass through the orifice. This was discovered by Ranque (1933) and later developed by Hilsch (1947). In memory of their contribution the Vortex tube is also known as Ranque-Hilsch vortex tube (RHVT). Analytical study on vortex tube was discussed by Lay (1959). Soni and Thomson (1975) gave the expressions for designing vortex tube. Hartnet and Eckert (1957) investigated with large size vortex tube. Gao (2005) investigated that the entry to the hot end is important for the energy separation. Behera et al., (2005) carried out simulation of vortex tube using CFD. Arjomandi and Yenpeng (2007) used new hot end plug which improved the performance of vortex tube. Kirmaci (2009) used statistical method to optimize the vortex tube. RHVT has the following advantages compared to the normal commercial refrigeration device. Simple in constructions, no moving parts, no chemicals, light weight, low cost, maintenance free, instant cold air, durable for its application. Therefore, if compactness, reliability and lower equipment cost are the main factors, then the vortex tube are recommended for spot cooling. Now lot of research works is going on the vortex tube to improve its performance.

II. Working Principle

Compressed air at high pressure enters the vortex tube through tangential nozzle where the flow gets accelerated. Due to tangential entry, the air has high velocity and rotates at very high speed. Thus the air has whirling or vortex motion in vortex chamber, which subsequently spiral down the tube to right side (depends on the direction of spiral). The central core of the air is reversed by means of a conical valve, which control the pressure in the system. The end of the cold pipe, which built up with the vortex chamber, is fitted with a washer that has the half the diameter of the pipe. Washers with different diameter are also used to adjust the system. The reversed air at low temperature moving through the washer to the cold section. Thus cold air is produced at the left side of vortex chamber. Hot air is produced at the right side through the conical valve.

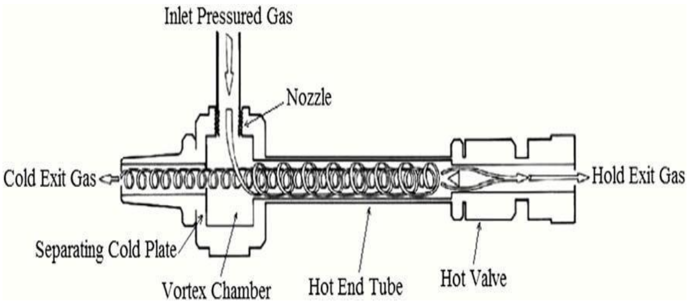


Fig. 1. Vortex tube.

III. Important Definitions

In this section, a few important terms commonly used in vortex tube work are defined.

A. Coefficient of Performance (COP):

To find the coefficient of performance (COP) defined as a ratio of cooling rate to energy used in cooling, the same principle of adiabatic expansion of ideal gas is employed and the equation becomes

$$COP= QC/W$$

and

$$C.O.P = \eta_{ab}.\ \eta_{ac}.\ [(Pa/Pi)(\gamma-1)/\gamma]$$

where η_{ab}, η_{ac}, Pi, Pa and γ are the adiabatic efficiency, air compressor efficiency, inlet pressure, atmosphere pressure and specific heat ratio, respectively.

B. Adiabatic Efficiency (η_{ab})

To calculate the cooling efficiency of the vortex tube, the principle of adiabatic expansion of ideal gas is used. As the air flows into the vortex tube, the expansion in isentropic process occurs. This can be written as follows: (ηab) and

$$\eta_{ab} = [\Delta Th/(\Delta Th + \Delta Tc)]^* \, (\Delta Tc/\Delta T'c)$$

in which ηab is the adiabatic efficiency and ΔT_h is the temperature raise of Hot air tube and ΔTc is the temperature drop of Cold air tube and ΔT'c Static temperature drop due to expansion, respectively.

C. Cold Orifice Diameter (β)

Cold orifice diameter ratio (β) is defined as theratio of cold orifice diameter (d) to vortex tube diameter (D).

$$\beta = d/D.$$

IV. Applications of Vortex Tube

Vortex flows or swirl flows have been of considerable interest over the past decades because of their use in industrial applications, such as furnaces, gas-turbine combustors, dust collectors, Cutting Tools and Shrink Fitting Cooling Of Gas Turbine Rotor Blades and Vortex Tube For Carbon Dioxide Separations.

The following applications as drafted below.

A. Vortex Tube Based Refrigeration

The Vortex Tube Based Refrigeration (Fig. 2) Refrigeration of food and medicine is an extensive problem. Fishing communities living on the coast line are also dependent on cold storage facilities for storing a day's catch. Usually conventional cold storage rooms are expensive for a local fisherman to afford. Conventional refrigerators are expensive to buy for an average person. Another important problem is transport of medicines, specifically vaccines from one place to another. Several vaccines require storage at low temperatures.

Thus the distance a medicine can be delivered via road is very limited. Thus many remote areas do not receive vaccines at local hospitals.

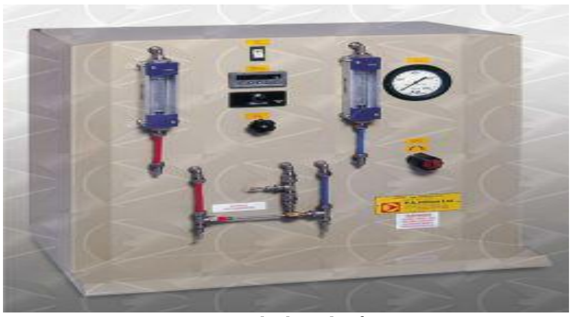
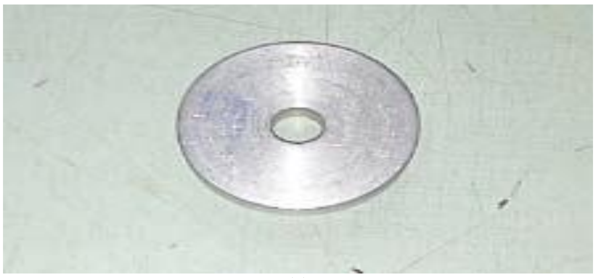


Fig. 2. Vortex tube based refrigeration.

V. Literature Review of Vortex Tube

The vortex tube was first discovered by Ranque [1, 2], a metallurgist and physicist who was granted a French patent for the device in 1932, and a United States patent in 1934. The initial reaction of the scientific and engineering Communities to his invention was disbelief and apathy. Since the vortex tube was thermodynamically highly inefficient, it was abandoned for several years. Interest in the device was revived by Hilsch [3], a German engineer, who reported an account of his own comprehensive experimental and theoretical studies aimed at improving the efficiency of the vortex tube. He systematically examined the effect of the inlet pressure and the geometrical parameters of the vortex tube on its performance and presented a possible explanation of the energy separation process. An experimental study was made by Scheper [22] who measured the velocity, pressure, and total and static temperature gradients in a Ranque–Hilsch vortex tube, using probes and visualization techniques. He concluded that the axial and radial velocity components were much smaller than the tangential velocity. His measurements indicated that the static temperature decreased in a rAdially outward direction. This result was contrary to most other observations that were made later. K. Kiran kumar Rao et al. [8] this paper presents experimental results by the different investigators on the effect of various geometrical parameters, like nozzles, orifice, conical needle modifications, and different material like metallic and nonmetallic and experiment, to improve cop, cooling performance of vortex tube under these conditions listed below. It is clear to that always the performance of vortex tube is directly proportional to inlet compressed air. Geometry for cold conical valves is improving at 45° valve and 90° a best result. The effect of the conical hot tube also influencing on cop. With the cooling of a hot tube are respectively, 5.5 to 8.8% and 4.7 to 9% higher than those of RHVT without the cooling (insulation only). K. Kiran Kumar Rao et al. [9] to study the effect of geometrical parameters on vortex tube made of two types of homogeneous wood to check the performance by using compressed air as a working fluid .The data was presented till date of the experimental work carried out by researchers for optimum performance of a vortex tube made of Rose wood and Sapota wood parameters such as the length of VT to its inlet diameter (L/ D) ratio as 24, use of different material in developing the vortex tube and its effect are discussed in detail.

VI. Fabrication of Vortex Tube



(a)

(b)

(c)

Fig. 3. Fabrication of aluminium vortex tube parameters: (a) diameter orifices and (b) the control valve (c) the hot tube.

A diaphragm is the most important part to be manufactured in the vortex tube. The diameter orifice (Fig. 3a) it is manufacturing, modelling and designed by using aluminium material. The thickness is 9mm and the outer diameter is 25mm and hole of 8mm is made at the centre. A control valve is major part to be fabricated in the vortex tube. The control valve (Fig. 3b) it is fabricated, modelling and drafting by using mild steel material. The importance of control valve lies in building up a pressure, which causes flow through a diaphragm. There will be a stagnation zone should not disturb the flow pattern in chamber extension. Hence the hot tube is inserted between the extension and the valve. A hot tube is the main part to be fabricated in the vortex tube. The hot tube (Fig. 3c) it is fabricated, modelling and design by using aluminium material. the length of hot tube is135mm and the through hole 12.5 diameter is made external threads of 1.5mm pitch are made on either side to length of 20mm.

VII. Observations and Calculations

The experimental investigation was conducted to find the effect of different orifice diameters and inlet pressures on the performance of vortex tube. After conducting the experiment the observations are noted as given below: For different Orifice diameter (d) at different input pressure by using aluminum material.

TABLE I. Summary of experimental studies on vortex tubes (Aluminium Orifice diameter: 8mm).

S. N o	Pi, bar	(Tc)0C	(Th) 0C	ΔT=Th-Tc 0C	ΔT c, 0C	ΔT h, 0C	μ	ηAdia batic	cop
1	7	9	51	42	18	24	0.57	0.89	0.23
2	6	10	50	42	17	23	0.57	0.90	0.24
3	5	12	48	36	15	21	0.58	0.87	0.28
4	4	12	47	35	15	20	0.57	0.97	0.29

VIII. Results and Discussion

The graph shows the effect of orifice diameter and pressure on the COP. As the inlet pressure increases, the COP is decreased. At 7 bar pressure COP is minimum as 0.9 with orifice diameter 4mm. At 4 bar pressure COP is maximum as 0.29 with orifice diameter 8mm Aluminum material: After evaluating the performance of vortex tube by varying the orifice diameters and inlet pressures it was found that the vortex tube with 8mm diameter orifice and at a pressure of 7 bar gives the best performance. As shown [Table I].

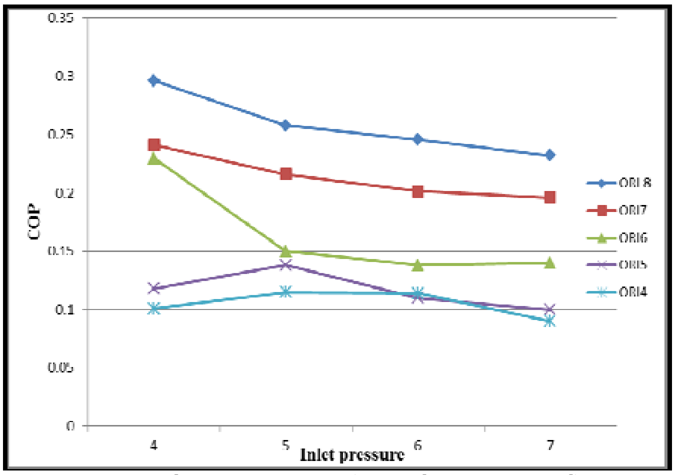


Fig. 4. Inlet pressure vs COP (From Aluminum material)

IX. Conclusion

The well suited diameter orifice (8mm)at pressure 7 bar for getting superlative cooling effect (9^{0C}) from Aluminium material. The felicitous orifice diameter (8mm) at pressure 7 bar for getting utmost heating effect (51^{0C}) from Aluminium material. The convenient diameter orifice(4mm)at pressure 7 bar for getting poor Co-efficient of performance (0.09) from aluminium material. The adaptable diameter orifice (4mm) at pressure 7 bar is gives supreme Co-efficient of performance (0.2964) from Aluminium material.

X. Future Scope

The vortex tube's ability to separate two phase gas mixtures based on density may enable high performance, multi-stage cryogenic refrigeration systems. The vortex tube has the potential to improve the performance of cryogenic refrigeration system. The vortex tube has potential uses in automobiles for air conditioning and spot cooling/heating purposes. There is scope for using the vortex tube as a dust trap. We can increase number of inlet air entries. We can increase number of inlet air entries. Experiments are also possible with varying the length of Cold ends and Hot ends .We can try different types of fluids like carbon dioxide, hydrogen as inlet element. Same Vortex tube as we have manufactured can be tested by using water as cooling agent. Also the vortex tube may be used for flame propagation in furnaces, jet propulsion, etc.

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