A Study and Fabrication of Vortex Tube

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Abstract— Refrigeration plays vital role in developing countries primarily for the preservation of food, medicine and for air conditioning. Conventional refrigeration systems are using Freon as a refrigerant. As they are the main cause for depletion of ozone layer, extensive research work is going on alternate refrigeration systems. Vortex tube is a non-conventional cooling device, having no moving parts which will produce cold air and hot air from the source of compressed air without affecting the environment. An experimental investigation is to be performed in order to realize the behavior of a vortex tube system. In this work attention has to be focused on the classification of parameters affecting vortex tube operation. The effective parameters are divided into two different types, namely geometrical and thermo-physical ones. The reliable test rig is to be designed and constructed to investigate the effect of geometrical parameters like diameter and length of main tube, diameter of outlet orifice, and shape of entrance nozzle. The thermo physical parameters are inlet gas pressure, types of gas, cold gas mass ratio and moisture of inlet gas.
Keywords: Vortex tube, Refrigeration, Orifice, Nozzle

I. Introduction

In the days of power crisis much more importance should be given to power saving and energy conservation. Efforts being concentrated on finding the new resources of energy or method of saving energy. For example in automobile catalytic converter, in the same sequence we had developed the method to utilize the waste heat in domestic refrigerator. The aim is to have refrigerator and heating oven side by side without spending additional energy. Refrigerator has become an essential commodity rather than need. Very few of us are aware about the fact that lot of heat is wasted to ambient by the condenser of refrigerator. If this energy can be utilized effectively then it will be added advantage of commodity.

II. Literature review

L.H. saidiin 2003 performed trial and error exploration has been executed to achieve complete behavior of vortex tubing system.

Giorgio De Observara et al perused upon Ranque-Hilsch vortex tubing as well as made their view level in vortex tubing has become employed for several years in numerous architectural purposes.

Philippe Bournot outlined by their document offers ant 3D statistical style of Ranque-Hilsch vortex tubing while using industrial CFD code (Fluent) to study the effect in the cold stop diameter in the strength separating system into the vortex tubing, this constant point out presumption as well as practical factors reveals that the disturbance design should be used to stand for its influence.

Y.T.Wu individually perused in vortex tubing as well as figured vortex is really a simple strength separating gadget which can be sleek and stylish as well as all too easy to produce also to operate.

III. Vortex tube and working

The vortex tube was discovered in 1930 by French physicist Georges Ranque. Vortex was the first company to develop this phenomenon into practical. Here’s how it works.

Fluid that rotates about an axis like a tornado is called a vortex. A vortex tube creates a vortex from compressed air and separates it into two air streams-one hot and one cold. Compressed air enters a cylindrical generator which is proportionally larger than the hot (long) tube where it causes the air to rotate.

Compressed air is passed through the nozzle as shown in figure 1. Here, air expands and acquires high velocity due to particular shape of the nozzle. A vortex flow is created in the chamber and air travels in spiral like motion along the periphery of the hot side. 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 core of the hot side starts from high pressure region to low pressure region. 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 air stream in forward direction gets heated up. The cold stream is escaped through the diaphragm hole into the cold side , while hot stream is passed through the opening of the valve. By controlling the opening of the valve, the quantity of the cold air and its temperature can be varied.

IV. Material selection

The knowledge of materials and their properties is of great significance for the design engineer. The machine element should be made of such a material which has properties suitable for condition. In addition to this design, engineer must be familiar with the effect which manufacturing process and its treatment have on properties of material. To fulfill the specific need, following material have been selected

Material	Properties
Mild Steel C 0.20% - 0.30% Mn 0.30% - 0.60%	Tensile Strength 44.54 Kgf/mm2 Yield strength 28 Kgf/mm2 BHN 170
Copper	Specific gravity 8.9 Melting point 10830C Tensile strength 150 Mpa – 400 Mpa
Aluminium	Specific gravity 2.7 Melting point 6580C Tensile strength 90 Mpa-150 Mpa
Nylon	Density 1.05 g/cm3 Tensile Strength 66 Mpa Melting Temperature 2180C

Table 1: Material properties

V. Design

In general, there are two design features associated with a vortex tube, namely, maximum temperature drop vortex tube design for producing small quantity of air with very low temperatures and maximum cooling effect vortex tube design for producing large quantity of air with moderate temperature. These two design considerations have been used in study for increasing the heat transfer rate during forward motion for swirl air and reversed flow of axial air. The parameters investigated in the study to understand their inter relationships and their effects on the performance of the vortex tube are:

- Nozzle diameter
- Cold orifice diameter
- Length of the tube
- Area at the hot end

A. Performance equation for vortex tube:

The performance of the vortex tube is marked by cooling effect (ΔTc) and heating effect (ΔTh). This is defined as follows:

$$\Delta Tc = Ta - Tc \quad \text{(Equation 1)}$$

$$\Delta Th = Th - Ta \quad \text{(Equation 2)}$$

Adding the above equations, the total temperate difference is obtained as in the following:

$$\Delta T = Th - Tc \quad \text{(Equation 3)}$$

For isentropic process calculating the temperature difference:

$$\Delta Tis= Ta\,(1- (P1/P2)(\gamma-1/\gamma)) \quad \text{(Equation 4)}$$

Where P1 ,P2 , γ are the inlet air pressure, the atmospheric pressure and the specific heat ratio respectively. As the air flows in to the vortex tube, the expansion in isentropic process occurs. The isentropic efficiency can be written as follows:

$$\eta is= \Delta T / \Delta Tis \quad \text{(Equation 5)}$$

The vortex tube can be considered asboth a cooling and heating. The efficiency of cooling can be expressed in terms of coefficient of performance (COP) explained as follows:

$$COP = Qc / W \quad \text{(Equation 6)}$$

Where Qc = Discharge
W = work done

B. Design Parameters:

Inner tube diameter	2.032 cm	D
Cold orifice diameter	1.028 cm	0.5 D
No of nozzle inlet	5	Depending on air flow rate
Hot end lenght	92.71 cm	45 D
Cold end lenght	20.32 cm	10 D
Pressure guage	0-2 bar	Experimental set up

C. Geometrical effect on the tube Performance

The effects of geometrical parameters on vortex tube performance have been investigated by many researchers using both experimental and numerical methods. It has been reported that when different geometrical parameters were selected for testing vortex tube, such as length and diameter of tube, shape and size of the inlet nozzle, cold and hot exit, structure of the tube, the temperatures of the generated cold and hot streams varied. However, there has not been an explanation that can be used to explain all the effects of the variable parameters on the tube performance.

D. Tube Length

It was reported that the length of the tube should be longer that the critical length to achieve significant temperature separation within the vortex tube. When the vortex tube is shorter than the critical value, the separating vorticities between the cold core and multi-circulation region became weaker or even disappear, the cold flow will subsequently mix with the hot flow from the multi-circulation region. Hence, the temperature separation in a very short vortex tube will not be significant. When the length of the vortex tube approximates or is longer that the critical length, the separation of the cold region and multi circulation region i.e. the hot region is ensured by the tube length and provides a better performance of the temperature separation. The critical length is different for vortex tube with different tube diameters.

E. Tube Diameter

The performance of the vortex tube is also function of tube diameter. When optimized, the diameter of the vortex tube can provide perfect separations of the cold and hot regions, which therefore dictates the performance of the temperature separation. When the diameter of the vortex tube is too small or too large, mixture of hot and cold streams inside the tube or mixture of the cold streams and sucked ambient air, can lead to reduction in temperature drop.

F. Ratio of Tube Length over Diameter

It has been reported that the ratio of tube length over the diameter needs to be greater than 20 in order to have significant temperature separation in a vortex tube. Once the ratio is greater than 45 then, there is no further effect on performance of the vortex tube.

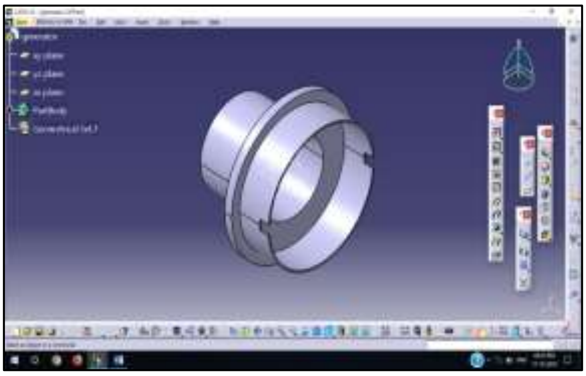
G. Vortex angle

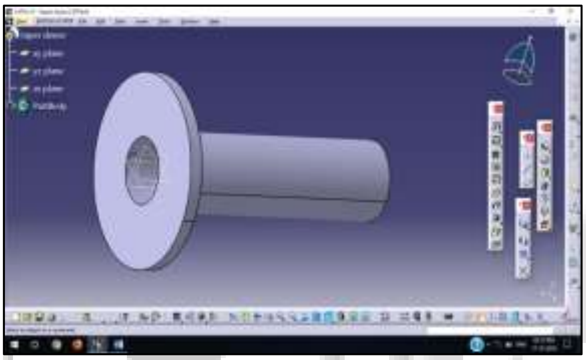
A new geometrical parameter, termed as vortex angle, has been investigated; it has been observed that the introduced vortex angle had negative effects on the magnitude of the temperature differential achieved. Based on the proposed explanation the introduced vortex angle leads to decrease of the tangential velocity and an increase in the axial velocity since both the temperature drop and temperature rise are caused by the strong swirling flow, the decrease of tangential velocity is the reason for the reduction of temperature separation in vortex tube with a vortex angle generator installed.

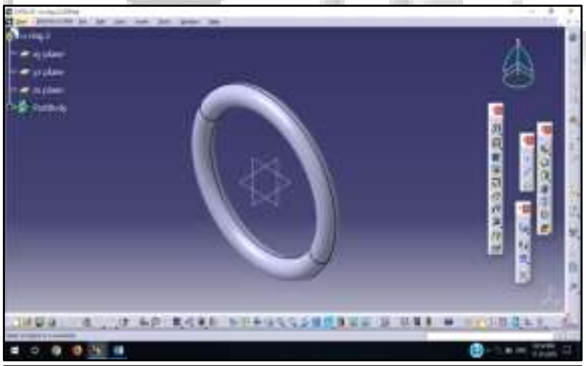
H. Inlet Nozzle

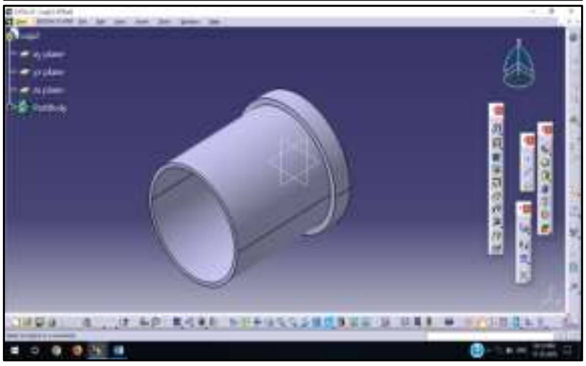
The strong swirling flow, which is the reason for the temperature separation in the vortex tube, is generated by the injected high speed fluid through the inlet nozzle, so the inlet nozzle which exhibits good characteristic in generating the swirling flow is the primary component in generating the two streams which results in large temperature difference within vortex tube. Dimension of inlet nozzle cannot exceed a critical value in order to generate the strong swirling flow generally, an increase in inlet nozzle number leads to greater injected flow and symmetric flow in the tube, both of which leads to impressed temperature separation. Furthermore, too many inlet nozzles which cause high back pressure inside the tube and lead to decrease of swirl velocity resulting in a reduction of the temperature separation.

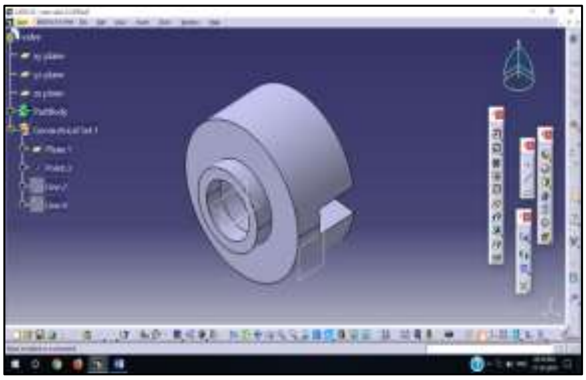
I. Catia Models

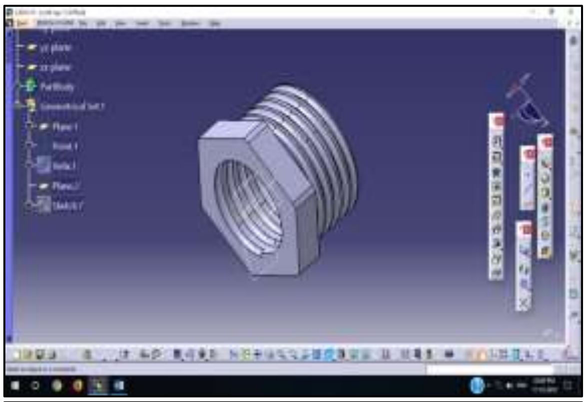


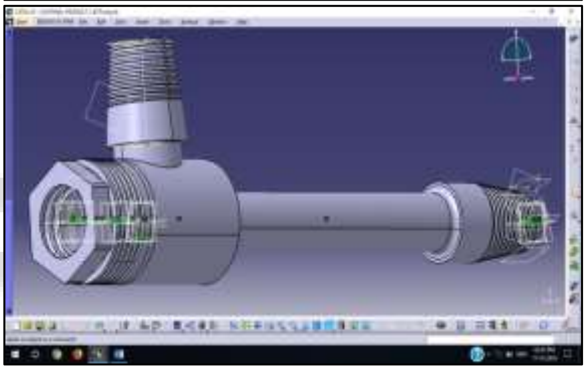












VI. TEST RESULTS

Sr. No.	Pressure	Hot Temp	Cold Temp
1	4 bar	63.55 C	20.8 C
2	3 bar	61.50 C	23.5 C
3	2 bar	59 C	25.8 C
4	1 bar	49.11 C	29.2 C

Table 3: Result Table

A. Calculations:

Observations
Environment temperature = 32^o C
P = 4 bar
Atmospheric pressure = 1.013 bar
Inlet pressure Pi = 4 bar
Inlet temperature $T_i = 32^o$ C
Cold end temperature $T_c = 20.8^o$ C
Hot end temperature $T_h = 63.55^o$ C
1) Cold drop temperature $\Delta T_c = T_i - T_c$
$= 32-20.8$
$= 11.2^o$ C
2) Hot rise temperature $\Delta Th = T_h - T_i$
$= 63.55-32$

$= 31.55^o$ C

3) Temperature drop at two ends $\Delta T = T_h - T_c$

$= 63.55-20.8$

$= 42.75^o$ C

4) Cold mass fraction

$$m = \Delta Th / (\Delta Th + \Delta T_c)$$
$$= 31.55 / (31.55 + 11.2)$$
$$= 0.738$$

VII. CONCLUSION

Thus, Test rig is designed and parameters like diameter and length of main tube, diameter of outlet orifice, and shape of entrance nozzle are studied. Also thermo-physical properties like inlet gas pressure, types of gas, cold gas mass ratio and moisture of inlet gas are studied.

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