International Journal of Engineering Science Invention (IJESI)
ISSN (Online): 2319 – 6734, ISSN (Print): 2319 – 6726
www.ijesi.org ||Volume 7 Issue 8 Ver II || Aug 2018 || PP 33-39

Design and Performance Evaluation of a Vortex Tube Form by a Delrin Material

Ramesh ganugapenta[1], G.R Selokar[2], P VenkatRathnam[3]
[1]*(Research scholar, Dept. of Mech, Sri Satya Sai University Of Technology& Medical Sciencies,Bhopal,MP.India)*
[2]*(Professor&Registrar, Dept. of Mech, Sri Satya Sai University Of Technology& Medical Sciencies,Bhopal,MP.India)*
[3]*(PG scholar, Dept. of Mechanical, Vemu Institute Of Technology, Chittoor, AP, India)*
Corresponding Author: Ramesh ganugapenta

Abstract :*Refrigeration assumes a noteworthy part in preparatory nations, essentially for the safeguarding of nourishment, prescription, and for aerating and cooling. Ordinary refrigeration frameworks are utilizing Freon as refrigerant. What's more, is the potential reason for draining Ozone layer, broad research is going on interchange refrigeration frameworks. Vortex tube is a non – regular cooling gadget, having no moving parts which will create icy air and hot air from the wellspring of compacted air without affecting nature. At the point when an elevated weight air is inventively infuse into the vortex chamber, a brawny vortex stream will be molded which will be split into two air streams. The present work predominantly centersaround Design and creating the vortex container of Delrin material, subsequent to manufacturing, the execution of the Vortex tube is assessed for various measurements of opening and channel weights. Cooling impact and Heating impact are chosen and COP as execution measures.The main objectives of the present work are described below:*
To determine the suitable orifice diameter for getting Cooling effect and Heating effect.
To find out the suitable inlet pressure for obtaining Cooling effect and Heating effect.
To validate the best diameter for the chosen performance measures of COP.

Keywords: *Vortex Flow,Orifice, Tangential Nozzle, Vortex chamber*

Date of Submission: 29-07-2018 Date of acceptance:16-08-2018

I. Introduction

The vortex tube, also known as the Ranque-Hilsch vortex tube (RHVT) 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 1931 by George Ranque, a French physics student, while experimenting with a vortex-type pump that he had developed, and then he noticed warm air exhausting from one end, and cold air from the other. Ranque soon forgot about his pump and started a small firm to exploit the commercial potential for this strange device that produced hot and cold air with no moving parts. However, it soon failed and the vortex tube slipped into obscurity until 1945 when Rudolph Hilsch, a German physicist, published a widely read scientific paper on the device.Much earlier, the great nineteenth century physicist, James Clerk Maxwell postulated that since heat involves the movement of molecules, we might someday be able to get hot and cold air from the same device with the help of a "friendly little demon" who would sort out and separate the hot and cold molecules of air.

Thus, the vortex tube has been variously known as the "Ranque Vortex Tube", the "Hilsch Tube", the "Ranque-Hilsch Tube", and "Maxwell’s Demon". By any name, it has in recent years gained acceptance as a simple, reliable and low cost answer to a wide variety of industrial spot cooling problems.

II. Working Of Vortex Tube

A compressed air is passed through the nozzle as shown in figure. 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 motion along the periphery of the hot side. Then, the rotating air is forced down the inner walls of the hot tube at speeds reaching 1,000,000 rpm.

The control valve restricts this flow. When the pressure of the air near the valve is made more than the outside by partly closing the valve, a reversed axial flow through the core of the hot side starts from high-pressure region. During this process, energy transfer takes place between reversed stream and forward stream and therefore air stream through the core gets cooled below the inlet temperature of the air in the vortex tube while the air stream in forward direction gets heated. The cold stream is escaped through the diaphragms hole into the cold side, while hot stream is passed through the opening of the control valve. By controlling the opening of the valve, the quantity of the cold air and its temperature can be varied

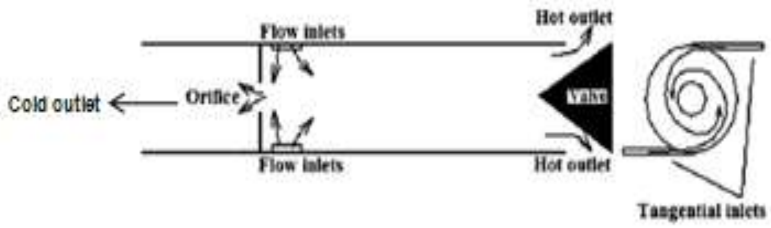


Figure: 1 Counter flow Vortex tube.

III. Theory Of Operation

The theoretical explanation given by various research workers differs from each other though they have tried to explain as to how does the pumping of heat from low to high temperature takes place in the absence of a mechanical device giving a flow of the core of cold air and the hot air around the peripheryas been tested experimentally by injecting smoke. This revealed the presence of a. When the compressed air expands through the nozzle the swirl motion is created. This h solid rotating core though there was considerable disturbance in the smoke due to swirl motion. The testing was also carried out using oil, which gave trace of helical path on the tube-wall with increasing pitch towards the hot end. The helix angle indicated that the axial component of the velocity is much less than the tangential component for almost the entire length of the tube.This energy supply is insignificant compared to pumping of energy from the core to the outer layer due to turbulent mixing in the centrifugal flow fields. As a result there is a flow of cold core surrounded by a hot concentric flow field. However, the pumping of energy from low to high temperature is still not uniquely proved though the flow fields for cold core and hot annular region have been well investigated.

a) **Temperature Separation Effect:** The Vortex Tube Creates two types of vortices: free and forced. In a free vortex (like a whirlpool) the angular velocity of a fluid particle increases as it moves toward the Center of the vortex-that is, the closer a particle of fluid is to the center of a vortex, the faster it rotates. In a forced vortex, the velocity is directly, proportional to the radius of the vortex-the closer the center, the slower the velocity.
b) **Humidity Effects:**A Vortex Tube does not separate humidity between hot and cold air-it temperature, the moisture will condense and/or freeze. When temperatures are below remains the same as the compressed air input. If the dew point of the air is higher than its freezing, the condensation is in the form of snow. This snow has a sticky quality from oil vapor and will eventually collect and block air passages

IV. Experimental Investigation

Prabakaran.J Andvaidyanathan.S “Effect Of Diameter Of Orifice And Nozzle On The Performance Of Counter Flow Vortex Tube”This paper focuses on the main factors that affecting the performance of vortex tubes are inlet pressure, L/D ratio, cold mass fraction, diameter of nozzle and orifice. In this paper the performance of the vortex tube is investigated with different diameters of orifice and nozzle. In this work an attempt is made to investigate the effect of orifice diameter and nozzle diameter on the performance of vortex tube. For the better cooling effect the optimum value of orifice diameter and nozzle diameter is found. **Maziar Arjomandi,** “An Investigation Of The Effect Of The Hot End Plugs On The Efficiency Of The Ranque-Hilsch Vortex Tube”This paper focuses on the effect of the size of hot nozzle on the performance of the Ranque–Hilsch vortex tube. Series of plugs were used in the experiment in order to find the relationship between the diameter of hot end plug and the performance of the vortex tube.In the experiments done in the current research, plugs with different diameters have been used while the shape and all other geometrical parameters of the tube have been kept the same. The tube thermal efficiency has been used as the parameter describing the tube performance for the different hot end plugs. Also the experiments for measurement of temperature and pressure have been done for total blockage of the hot end. The results of these experiments have been used for calculation of the tube efficiency in the extreme condition.**J. Prabakaran and S. Vaidyanathan,** “Effect Of Orifice And Pressure Of Counter Flow Vortex Tube”The effect of orifice diameter and inlet pressure is investigated and presented in this paper. In this work, an attempt was made to fabricate and test a counter flow vortex tube. The performance of vortex tube was evaluated at different working parameters and geometry parameters.**P K Singh, R G Tathgir, Gangacharyulu, G S Grewal** “An Experimental Performance Evaluation Of Vortex Tube”The experimental investigations were carried out based upon two designs, i.e., maximum temperature drop tube design and maximum cooling effect tube design. It is observed that the effect of nozzle design is more important than the cold orifice design in getting higher temperature drops. Cold fractions as well as adiabatic efficiency are more influenced by the size of the cold orifice rather than the size of the nozzle. Higher temperature drops are obtained in vortex tube made of maximum temperature drop tube design, whereas, more cold fraction and higher adiabatic efficiency are obtained with maximum cooling effect tube design. Length of the tube has no effect on the performance of the vortex tube.**Chengming Gao** "Experimental Study On The Ranque-Hilsch Vortex Tube"In this paper, various experiments on the different components of the RHVT have been done in order to investigate their influence. The experimental investigations of the performance of the RHVT with the cylinder type Pitot tube (CPT), single probe hot-wire anemometry (SPHWA) and thermocouple techniques are discussed. The measured velocity, pressure and temperature distributions inside the RHVT are presented and discussed. **G. F. Nellis and S. A. Klein** "Application Of Vortex Tubes To Refrigeration Cycles"In this paper, a semi-empirical model of the vortex tube is presented using one hypothesis regarding its underlying physics. Predictions made using this model are found to compare favorably with the limited experimental data that are available. The vortex tube model is integrated into a model of a vapor compression refrigerator and a Joule-Thomson cryogenic refrigerator. The potential for increasing the performance of a refrigeration cycle using the vortex tube is found to be extremely limited for the vapor compression cycle. However, it is shown that the vortex tube may present a significant opportunity to improve the performance of refrigeration systems using the Joule-Thomson cycle and may allow efficient operation at lower pressure ratios, with smaller recuperative heat exchangers, and with less expensive working fluids than are currently used. More complex cycles are discussed in which the vortex tube can be used to simultaneously perform phase and energy separation**Giorgio De Vera** "The Ranque-Hilsch Vortex Tube"This report goes over some of the major conclusions found from experimental and numerical studies since the vortex tube's invention. One of these studies showed that acoustic streaming caused by vortex whistle plays a large part in the Ranque-Hilsch effect. In addition, thermal and kinetic energy considerations have been used to explain temperature separation. There have also been plenty of numerical analyses that confirm earlier experiments.

V. Design Of Vortex Tube

MAIN BODY

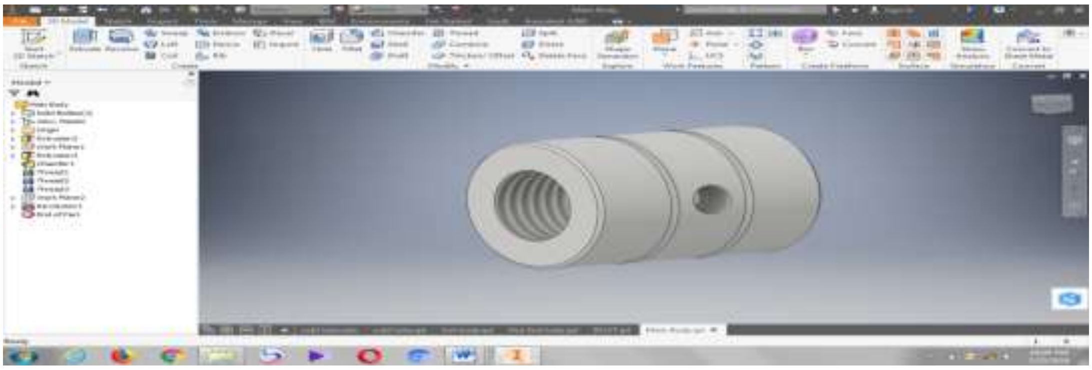


Figure:2. design of main body

Select the new file → part – create 2D & 3D objects ↳ standard .ipt ↲ created.
Part – 1 – create name – Main Body.
Select start 2D sketch → select plane to create sketch (X-Y) plane.

CIRCLE COMMAND*:*
Select circle command – draw the outer diameter & inter diameter Ø 45mm &Ø25m concentric circles finished sketch. Model exit:

EXTRUDE COMMAND:
Select extrude command.
Select symmetric 60mm length on the body.
Create work plane to length of the extrude body.
Than create new sketch in that in that plane (work plane –I) diameter Ø 10mm for center of the body.

THREAD COMMAND:
Select the tread file; click → face
Select inner circle (Ø 25mm) & length 60mm in threading (1-8UNC-2A).
Select the thread file ; click – face
Select center of the hole (Ø 10mm) & length 10mm in threading.

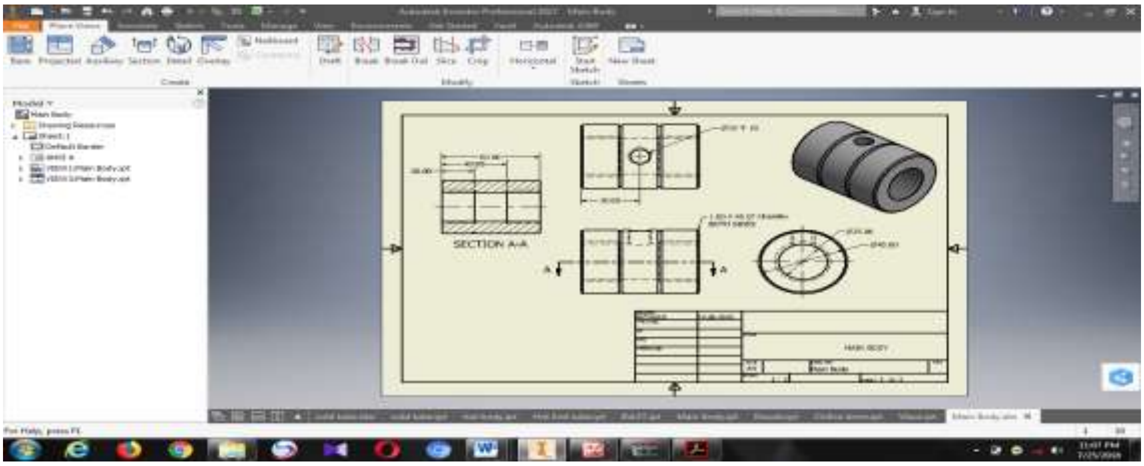
Create work plane – 2 to tangent at the extrude body.
Create two circles with diameter Ø 2mm from face, 20mm distance both side

REVOLVE COMMAND:

Select the revolve file; click → profile.
Cut the extrude body with two circles indicates the position of the inside the body.

CHAMFER COMMAND:

Select the chamfer file; click → Edge.
Select both side edge's (Dimensions – 1×450)
Finally save as main body model.



Create drawing for main body model to understand manufacturing
Save the file.
Then closed the inventor.

VI. FABRICATION OF VORTEX TUBE:

The vortex tube consists of the following components:
Main body
Cold tube
Hot tube
Inlet tube
Control valve
Diaphragms
Nozzle cum chambe

INLET TUBE:

A brass nipple is selected with diameter 4mm which threads are compatible with the inlet hole of the main body

Figure:4 Photo of fabricated Inlet

NOZZLE:

The nozzle is manufactured by using a Delrin alloy material. The outer diameter of nozzle is 24mm and a center hole of 15mm is made and a tangential hole is drilled at the top for air to enter tangentially.

Figure:5 Photo of fabricated Nozzle.

HOT END:

Delrin material of size 60mm diameter meters and 70mm length is used. First the material is turned to a diameter of 45mm and faced to a length of 40mm. The external threading of 14 TPI of the part that is attachable to main body is executed to the length of 18 mm, a hole with 37mm diameter to a depth of 33mm is drilled with an internal threading of 14 TPI to a length of 18mm at the control end side and three small holes one at center and two on each side of the center hole with 10mm diameter are drilled to facilitate the control valve and exit to hot air.

Figure:6 Photo of fabricated Hot end

VII. Important Definitions

In this segment, a few significantprovisosfrequently used in vortex tube work are clear.

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

$$C.O.P = \frac{\text{Cooling effect}}{\text{Work input}}$$

andC.O.P = ηab. ηac. [(Pa/Pi)(γ-1)/γ] (1)

whereηab, ηac , Pi, Pa and γ are the adiabatic efficiency, air compressor efficiency, inlet pressure, atmosphere pressure

ADIABATIC EFFICIENCY (η_{ab}):

To compute the cooling competence of the vortex tube, the rule of adiabatic expansion of ideal gas is applied. As the air flows into the vortex tube, the expansion in isentropic process occurs. This can be written as follows:

$$\eta ab = \frac{\text{actualcoolinggainedinvortextube}}{\text{Coolingpossiblewithadiabaticexpansion}}$$

and

ηab = [ΔTh/(ΔTh + ΔTc)]* (ΔTc/ΔT'c) (2)

in which ηab is the adiabatic efficiency and ΔTh 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.

ICY ORIFICE DIAMETER*(β):*

Cold orifice diameter fraction (β) /clear as the ratio of cold orifice diameter (d) to vortex tube diameter (D):

β=d/D. (3)

COLD AIR TEMPERATURE DROP(ΔTc):
Cold air hotnessslump or temperature decline is defined as the variation in temperature amid entry air temperature and cold air temperature:

$\Delta Tc = Ti - Tc.$ (4)

in which Ti is the way in air temperature and Tc is the cold air temperature

HOT AIR TEMPERATURE DROP (ΔT_h):
Hot air temperature drop or temperature raise is defined as the difference in temperature between Hot air temperature and entry air temperature:

$\Delta Th = Th - Ti.$ (5)

in which Ti is the entry air temperature and Th is the hot air temperature.

VIII. OBSERVATIONS AND CALCULATIONS

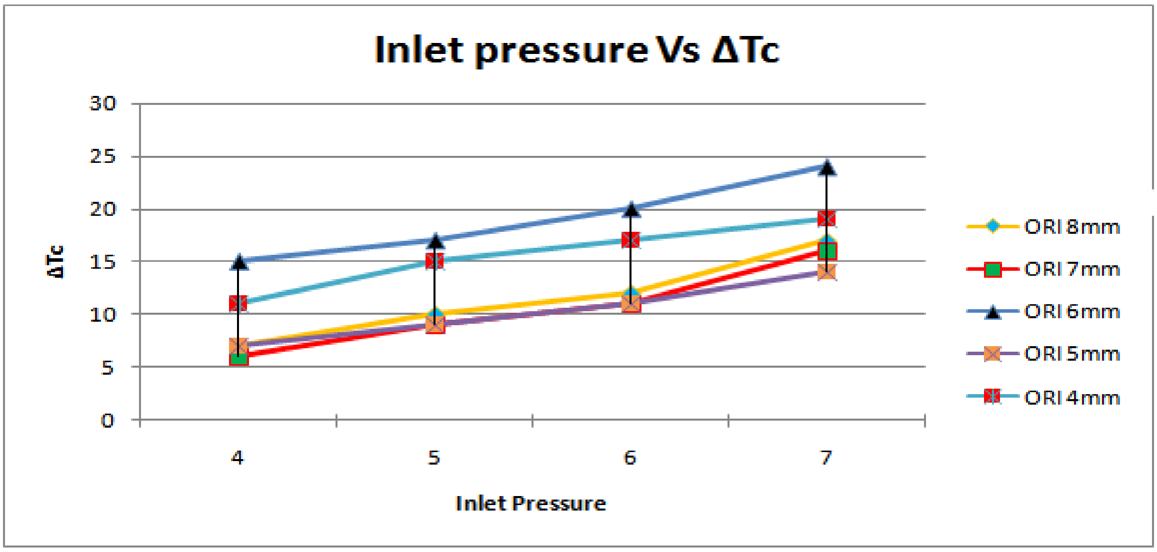
The experimental investigation was conducted to find the effect of different orifice diameters and inlet pressures on the performance of vortex tube. After conducting the experiment the observations are noted as given below:
For different Orifice diameter (d) at different input pressure.

ORIFICE DIA: 6MM

Pi, bar	(Tc),0C	(Th), 0C	ΔT= Th-Tc 0C	ΔTc, 0C	ΔTh, 0C	COP
7	3	58	55	24	31	0.30
6	07	56	49	20	29	0.297
5	10	53	43	17	26	0.294
4	12	50	38	15	23	0.32

Graphs: The graphs are drawn for the values obtained from the tabular columns.

INLET PRESSURE VS. $\square T_c$



The above shows the effect of orifice diameter and pressure on the ΔTc.
As the inlet the pressure increases, the temperature difference is increased.
At 7 bar pressure the orifice with 6mm diameter performs well and the maximum cold temperature drop is obtained as 24°c and the maximum temperature difference is obtained as 58°c.
At 4 bar pressure the orifice with 7mm diameter the performance is very poor and cold temperature drop is obtained as 06°c and the temperature difference is obtained as 30°c.

IX. RESULTS:

After evaluating the performance of vortex tube by varying the orifice diameters and inlet pressures it was found that the vortex tube with 6mm diameter orifice and at a pressure of 7 bar gives the best performance.

X. DISCUSSIONS:

The performance of the vortex tube was evaluated by conducting the experiment by varying the orifice diameters for various inlet pressures.
The least cold temperature obtained is 3˚C at 7 bar pressure for an orifice diameter of 6mm.
The highest hot temperature obtained is 51˚C at 7 bar pressure for an orifice diameter of 8mm
The maximum of 56˚C difference between hot and cold ends temperature and maximum of 29˚ C hot temperature drop and 17˚C cold temperature drop is obtained.

XI. CONCLUSION\

In this work the effect of orifice diameter and inlet pressures on the performance of vortex tube is investigated. For the better cooling effect the optimum value of orifice diameter is 6mm and inlet pressure is 7bar. As the minimum temperature in cold end is obtained as 30C and the maximum temperature obtained on hot end is 580C when atmosphere temperature is 270C, the vortex tube can be used for any type of spot cooling and heating applications. The results obtained by this technique have led to the following conclusions.
The Cold drop temperature ΔTc increases with increase in inlet air pressure.
The Hot temperature raise ΔTh increases with increase in inlet air pressure.
The C.O.P of the vortex tube decreases with increase in inlet pressure.
From the results obtained, it was found that the performance of the vortex tube is good for an orifice of 6mm diameter at a pressure of 7 bars.

The optimum end gate valve opening gives the best performance
The effect of nozzle design is more important than the cold orifice design in getting higher temperature drops.
The surface finish of the nozzle and the hot tube plays a great role in the performance of the vortex tube, good surface finish leads to the better performance, so care to be taken while fabrication of the parts to obtain to get good surface finish.
The graphs drawn are showing the effect of increasing the inlet pressure with the temperature drop shows an increase trend i.e. initially with increase in the inlet pressure the temperature drop increase linearly and after a certain pressure that temperature drop tends to becomes almost constant.

References

[1]. Ranque GJ. Experiments on expansion in a vortex with simultaneous exhaust of hot air and cold air. J PhysRadium (Paris) 1933;4:112–4 S-115, June. Also translated as General Electric Co., Schenectady WorksLibrary 1947; T.F. 3294.
[2]. Ranque GJ. Method and apparatus for obtaining from a fluid under pressure two outputs of fluid at differenttemperatures. US patent 1:952,281, 1934.
[3]. Hilsch R. The use of expansion of gases in a centrifugal field as a cooling process. Rev SciInstrum1947;18(2):108–13.
[4]. Scheper GW. The vortex tube; internal flow data and a heat transfer theory. JASRE Refrig Eng1951;59:9859.PprabhakaranTICLE IN PRE
[5]. Martynovskii VS, Alekseev VP. Investigation of the vortex thermal separation effect for gases and vapors. Sov Phys-Tech Phys 1956;1:2233–43.
[6]. Expermental performance analysis of vortex tube for various parameters (S.A.Mule) and yogeshbhosale.
[7]. Barwari RR. Effect of Changing Cone Valve Diameter on the performance of Uni-Flow Vortex Tube.
[8]. Kshiragar OM. Effect of Geometric Modifications on the Performance of Vortex Tube-A Review. International Journal of engineering Research and Applications. 2014;1(4):92-8.
[9]. Rao KKK, Pradeep GR, Ramesh A, Prabhakar K. Fabrication and experimental analysis of adiabatic vortextube.IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE). 2014: 11(5)
[10]. Darokar HV, Borse SL, Devade KD. Experimental investigations on divergent vortex tube with Convergent entry nozzles. InInternational Journal of Engineering Research and Technology 2012 Aug 30 (Vol. 1, No. 6 (August-2012)). ESRSA Publications.
[11]. Aydın O, Baki M. An experimental study on the design parameters of a counter flow vortex tube.EnergyJ 2006;31(14):2763–72.
[12]. Gao CM, Bosschaart KJ, Zeegers JCH, Waele ATAM. Experimental study on a simpleRanque–Hilschvortex tube. Cryogenics 2005;45(3):173–83.
[13]. Promvonge P, Eiamsa-ard S. Investigation on the vortex thermal separation in a vortex tuberefrigerator. ScienceAsia J 2005;31(3):215–23.
[14]. Singh PK. An experimental performance evaluation of vortex tube. IE(I) J-MC 2004;84:149–53.
[15]. Trofimov VM. Physical effect in Ranque vortex tubes. JETP Lett 2000;72(5):249–52.
[16]. Scheper GW. The vortex tube; internal flow data and a heat transfer theory. JASRE RefrigEng1951;59:9859.PprabhakaranTICLE IN PRE
[17]. Hartnett JP, Eckert ERG. Experimental study of the velocity and temperature distribution ina high-velocity vortex-type flow. Heat Transfer and Fluid Mechanics Institute, Stanford UniversityPress;1956. p. 135–50.

Ramesh ganugapenta "Design and Performance Evaluation of a Vortex Tube Form by a Delrin Material "International Journal of Engineering Science Invention (IJESI), vol. 07, no. 8, 2018, pp 33-39