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Fabrication and Experimental Analysis of Adiabatic Vortex Tube

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Abstract: *The vortex tube creates a vortex from compressed air and separates it into two air streams - one hot and one cold. This can be done by either a counter flow (or) a unit flow arrangement. In a vortex tube, the incoming air is separated into two streams, one stream rejects energy and hence become colder than the incoming air while the other receives the rejected energy and thus it has temperature elevated. The fabrication and experimental investigation was carried out based on different materials of Hot tubes like Mild steel, Aluminium and Copper used in fabrication by that the maximum hot air temperature and minimum cold air temperature were found. The fabrication and experimental investigation was carried out based on nozzle 8 mm diameter and orifice 6 mm diameter used in fabrication by that the maximum hot air temperature and minimum cold air temperature were found and by using same L/D ratio 22 with adiabatic process of Hot tube.*
Keywords: *Energy separation process, Ranque -Hilsch vortex tube Copper, Mild steel and Aluminium*

I. Introduction

Vortex tube is a simple device, which can cause energy separation. The principle of vortex tube is vortices produced by tangential velocity as a main driving force for the energy separation in the vortex tube. It consists of nozzle, vortex chamber, separating cold plate, hot valve, and hot and cold end without any moving parts. In the vortex tube, when works, the compressed air expands in the nozzle, then enters vortex tube tangentially with high speed, by means of whirl, the inlet air splits in low pressure hot and cold temperature streams, one of which, the peripheral air, has a higher temperature than the initial air, while the other, the central flow, has a lower temperature.

The physical mechanism inside an operating vortex tube can be observed physically, but difficult to explain. Compressed air is sent through the inlet nozzle (Figure 1). Swirl generators at the inlet plane create the vortex motion inside the tube. 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. This resulting radial temperature separation inside the vortex tube is also called the Ranque-Hilsch effect, named after its pioneers.

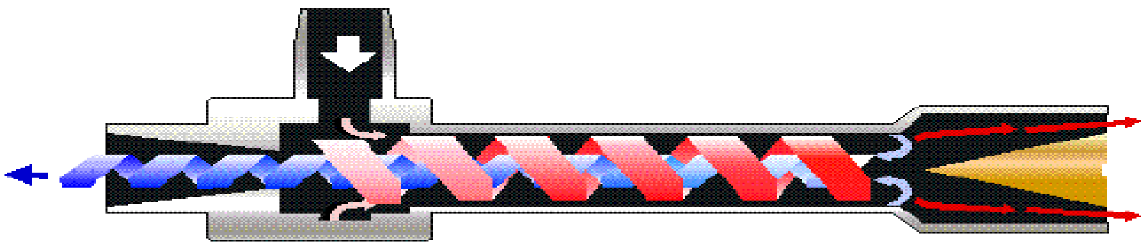


Figure 1: Vortex tube schematic

A compressed air is passed through the nozzle as shown in figure1. 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. The 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 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.. The air enters the main tube through the nozzle and forms a free vortex. Due to the centripetal acceleration, the vortex travels along the periphery of the tube and when it reaches the throttle valve, the rotation almost ceases, so there is a point of atmospheric pressure, a reverse axial flow starts. This flow comes into contact with the free vortex, which is moving with the increasing speed therefore the axial stream forms a forced vortex. The energy required maintaining the forced vortex in the reversed axial flow stream is supplied by the force vortex at the periphery.

Therefore, there is flow of energy (momentum) from the peripheral layer of air to the reversed axial flow stream at the axis. The rotational velocity of the free vortex at the periphery decreases gradually from the plane of the nozzle to the plane of the valve; therefore there is a relative sliding between the two adjacent air-planed, which are moving towards the valve. The result of this is a continuous transfer of energy from the plane of the nozzle to that of the valve. This gives the explanation why the heating of the air takes place as it proceeds towards the valve. The transfer energy from the inner core (from the region of forced vortex) to the periphery (into the region of free vortex) has not been explained satisfactorily. Theories abound regarding the dynamics of a vortex tube. Here is one widely accepted explanation of the phenomenon: Compressed air is supplied to the vortex tube and passes through nozzles that are tangent to an internal counter bore. These nozzles set the air in a vortex motion. This spinning stream of air turns 90° and passes down the hot tube in the form of a spinning shell, similar to a tornado.

Vortex Tube behaves in a very predictable and controllable way. When compressed air is released into the tube through the vortex generator, we get hot air out of one end of the tube and cold air out the other. A small valve in the hot end, adjustable with the handy control knob, lets adjust the volume and temperature of air released from the cold end. The vortex generator – an interchangeable, stationary part – regulates the volume of compressed air, allowing altering the air flows and temperature ranges can produce with the tube. "Cold Fraction": an important term for understanding Vortex Tube Performance. "Cold Fraction" is the percentage of input compressed air that's released through the cold end of the tube. As a rule of thumb, the less cold air release, the colder the air will be adjusting the cold fraction with the control knob. Cold fraction is also a function of the type of vortex generator that's in the tube, i.e., a "high cold fraction" or "low cold fraction" generator.

II. Fabrication Of Vortex Tube

The vortex tube consists of the following components:

a. Main body b. Cold tube c. Hot tube d Inlet tube e. Control valve f. Diaphragm g. Nozzle h. Chamber

2.1 Main Body:

For manufacturing of main body Used 75mm dia and 70mm length ingot of MS material Then it is turned to a diameter 70mm and length 60mm. internal threats of 14 TPI are cut throughout the length ,towards the hot tube side and right side threads are provided for fixing the hot pipe and cold pipe.

To provide inlet connection, drilled to a diameter of 20 mm and 16 TPI threads are cut. In order to facilitate convenient holding of inlet tube, shaping is done around the 20 mm diameter of the main body.

Plate No:2.1

2.2cold Tube

Using Mild steel piece of 85 mm length and 40 mm diameter ingot does this. This is turned to a length of 75 mm and 32 mm diameter. 14 TPI threads are cut on the outer periphery of the tube to a length of 25 mm, which is connected to main body. After this internal taper turning is done towards the part fixed to main body with small diameter 15 mm and big diameter 27 mm to a length of 75 mm.

Plate No:2.1

2.3 Hot Tube

1. Mild Steel material of size 20 mm diameters and 300 mm length is used. First the material is turned to a diameter of 13 mm throughout the length 285 mm. The external threading of 14 TPI of the part that is attachable to main body is executed to the length of 40 mm and threads of 14 TPI up to 25 mm are machined.
2. Aluminium material of size 20 mm diameters and 300 mm length is used. First the material is turned to a diameter of 13 mm throughout the length 285 mm. The external threading of 14 TPI of the part that is attachable to main body is executed to the length of 40 mm and threads of 14 TPI up to 25 mm are machined.
3. Copper material of size 20 mm diameters and 300 mm length is used. First the material is turned to a diameter of 13 mm throughout the length 285 mm. The external threading of 14 TPI of the part that is attachable to main body is executed to the length of 40 mm and threads of 14 TPI up to 25 mm are machined.

Plate no:2.3

2.4 Inlet Tube

Mild steel material of size 70 mm X 30 mm is turned throughout to a diameter of 25 mm and step turned the ends to 20 mm diameter up to 14.5 mm length on both sides.14.5 mm step turned part of the tube is threaded to 16 TPI, which is fitted over a main body. Then a hole of 9 mm is drilled throughout axially.

plate no:2.4

2.5 Control Valve

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. In long tube the vortex motion almost ceases by the time air reaches the valve. For a short tube vortex proceeds past the valve almost undistributed, if the needle valve is set along the axis. The globe valve creates the turbulence and mixing. This is the reason because of which we use the control valve perpendicular to the hot tube axis.

plate no:2.5

2.6 Diaphragm

Diaphragm is the most important part to be manufactured in the vortex tubes. It is manufactured by using Mild steel material size 15 mm thicknesses and 40mm diameter is taken and it is turned to 32mm diameter and 13mm thickness. The Diaphragms are manufactured as diameter 6mm

Plate no:2.6

2.7nozzle

The nozzle is manufactured by using a Mild steel material of thickness 15mm and diameter 40mm. This Mild steel piece is turned to a diameter of 32mm. Central hole is drilled to a diameter of 20mmand tangential cut opening 8mm by using a drill bit. A tangential cut is given to the nozzle by using hacksaw blade.

Plate no:2.7

Plate no::2.8 PARTS OF VORTEX TUBE

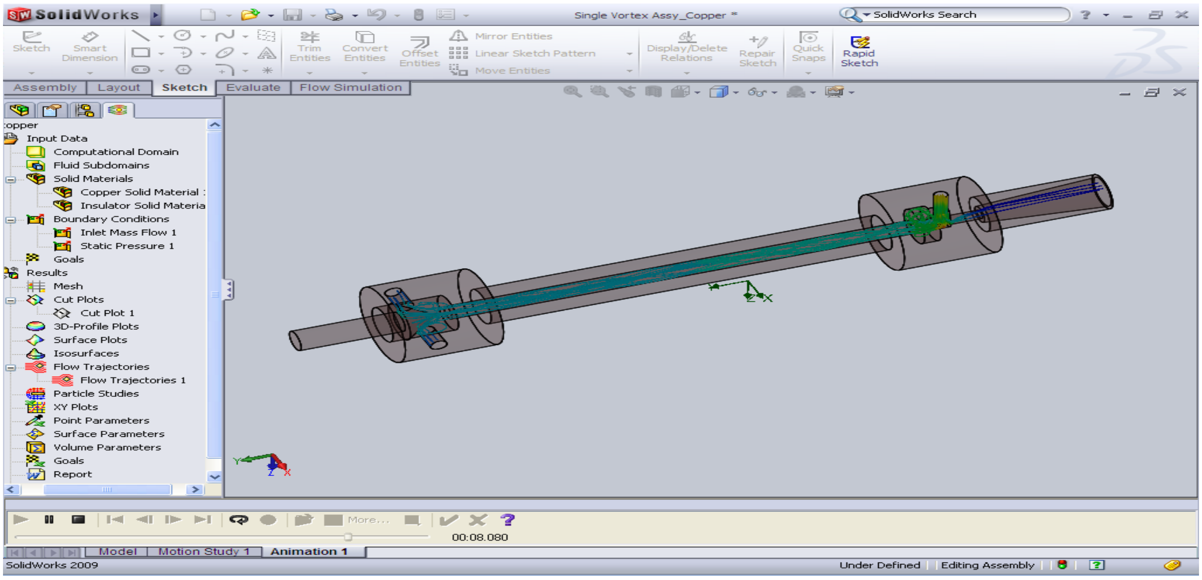


Plate no:2.8.1 FLOW TRAJECTORY OF VORTEX TUBE

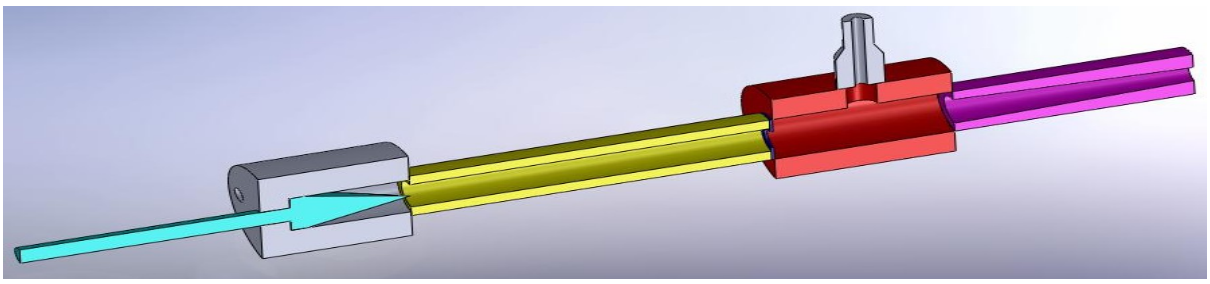


Plate no:2.8.2 SECTIONAL VIEW OF VORTEX TUBE

III. Properties Of Materials

31.Mild Steel

The calculated average industry grade mild steel density is 7861.093 kg/m3. Its Young's modulus, a measure of its stiffness is around 210,000 M Pa.

A moderate amount of carbon makes this steel different from other types. Carbon atoms get affixed in the interstitial sites of the iron lattice, making it stronger and harder. However, the hardness comes at the price of a decrease in ductility.

Compared to other types of steel, this type is ideal for welding purposes, as it conducts electric current effectively without tarnishing the metal surface in any way.

Mild steel has ferromagnetic properties, which make it ideal for manufacture of electrical devices and motors. It yields itself easily to magnetization.

Unlike other grades of carbon steel, which tend to be brittle, mild steel is hard, yet malleable, making it the ideal choice for the construction of pipelines, construction materials and many other daily use products like cookware.

Mild steel can be machined and shaped easily due to its inherent flexibility. It can be hardened with carburizing, making it the ideal material for producing a range of consumer products.

The high amount of carbon also makes it vulnerable to rust. Naturally, people prefer stainless over mild steel, when they want a rust free technology. It is also used in construction as structural steel, besides finding applications in the car manufacturing industry

3.2 Aluminium

Is a strong, malleable metal element, has a low density, is a good conductor of heat and electricity, can be polished to give a highly reflective surface.

3.3copper

Copper is an excellent electrical conductor. Most of its uses are based on this property or the fact that it is also a good thermal conductor. However, many of its applications also rely on one or more of its other properties. For example, it wouldn't make very good water and gas pipes if it were highly reactive. On this page, we look at these other properties:

a good electrical conductor, a good thermal conductor, corrosion resistant. antibacterial, easily joined ductile, tough , non magnetic, attractive colour, recyclable ,catalytic

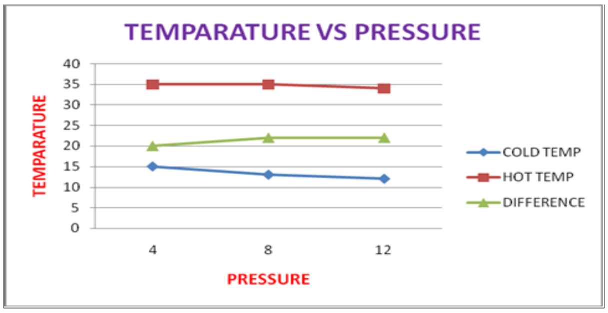
IV. Analysis Of Vortex Tube

4.1 Mild Steel

Length of the Hot pipe = 285mm Diameter of the hot pipe = 13mm L/D ratio=22 Room Temperature=37 ^{0}C

SL. NO	Diameter of the NOZZLE (mm)	Diameter of the DIAPHRAM(mm)	PRESSURE (Kg/Cm^2)	COLD TEMP ^{0}C	HOT TEMP ^{0}C
1	8	6	4	15	35
2	8	6	8	13	35
3	8	6	12	12	34

Table4.1



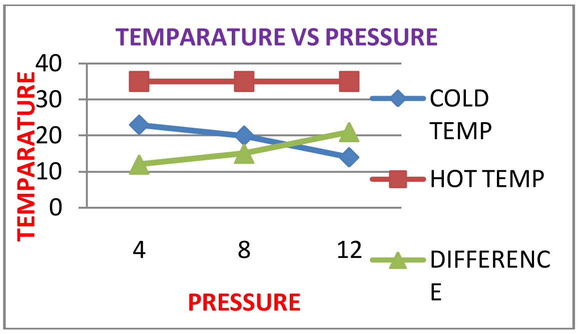
Graph no:4.1

4.2 Aluminium

Length of the Hot pipe = 285mm Diameter of the hot pipe = 13mm L/D ratio=22
Room Temperature=37 ^{0}C

SL. NO	Diameter of the NOZZLE (mm)	Diameter of the DIAPHRAGM (mm)	PRESSURE (Kg/Cm^2)	COLD TEMP ^{0}C	HOT TEMP ^{0}C
1	8	6	4	23	35
2	8	6	8	20	35
3	8	6	12	14	35

Table 4.2



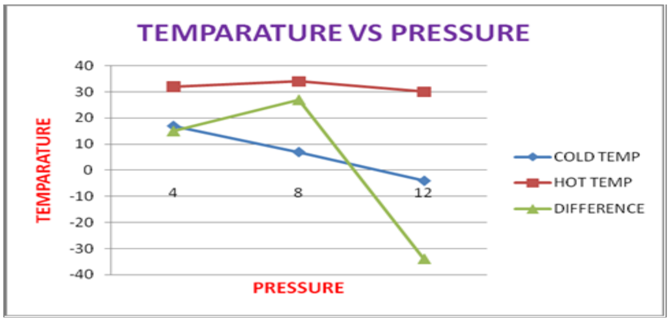
Graph no:4.2

4.3 Copper

Length of the Hot pipe = 285mm   Dia of the hot pipe = 13mm   L/D ratio=22   Room Temperature=37 ^{0}C

SL. NO	DIA OF THE NOZZLE (mm)	DIA OF THE DIAPHRAGM (mm)	PRESSURE (Kg/Cm^2)	COLD TEMP ^{0}C	HOT TEMP ^{0}C
1	8	6	4	17	32
2	8	6	8	7	34
3	8	6	12	-4	30

Table4.3



Graph no:4.3

V. Results:

5.1 We obtained best results when the length (L) 285mm.diameter of the hot tube (D) 13mm and L/D ratio with 22 of Aluminium ,Mild steel and Copper material.

5.2. After analysis the material of Copper the minimum and maximum température has been obtained -4^{0}C and 30^{0}C at a pressure of 12kg/cm^2

5.3. After analysis the material of Aluminium and the minimum and maximum température has been obtained 14^{0}C and 35^{0}C at a pressure of 12kg/cm^2

5.4. After analysis the material Mildsteel of the minimum and maximum température has been obtained 12^{0}C and 34^{0}C at a pressure of 12kg/cm^2

5.5 After analysis the performance of Vertex tube is directly praportional to the Pressure.

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