PERFORMANCE AND EVALUATION OF VORTEX TUBE WITH DIFFERENT PARAMETERS

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ABSTRACT

The vortex tube is a simple and eco friendly device generates both hot and cold air simultaneously as its two ends using a source of pressurized air. The compressed air is enters tangentially through nozzle with high velocity expands and form a swirl motion. During this flow pattern energy transfer takes place resulting in formation of hot and cold streams at its two ends.
Separating cold and hot streams by using vortex tube can be used for various industrial applications, where hot air and cold air is required simultaneously. the vortex tube parameters like material , lengths inlet and exit plays key roles to achieving maximum proficiency the present investigation is carried out for two different material (copper and brass) at different lengths and pressures .

KEYWORDS: *vortex tube, pressure, tube lengths, cop of vortex tube.*

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.When high-pressure gas is tangentially injected into the vortex chamber via the inlet nozzle, a swirling flow is created inside the vortex chamber. In the vortex chamber, part of the gas exists via the cold exhaust directly, and another part called as free vortex swirls to the hot end, where it reverses by the control valve creating a forced vortex moving from the hot end to the cold end. Heat transfer takes place between the free end and the forced vortices there by producing two streams, one hot stream and the other is cold stream at its ends.

II. WORKING

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.

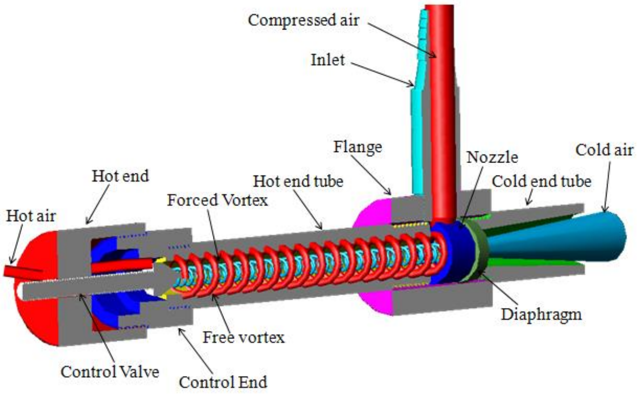


Fig: 2.1 Sectional view of Vortex tube.

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 periphery. When the compressed air expands through the nozzle the swirl motion is created. This has been tested experimentally by injecting smoke. 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.

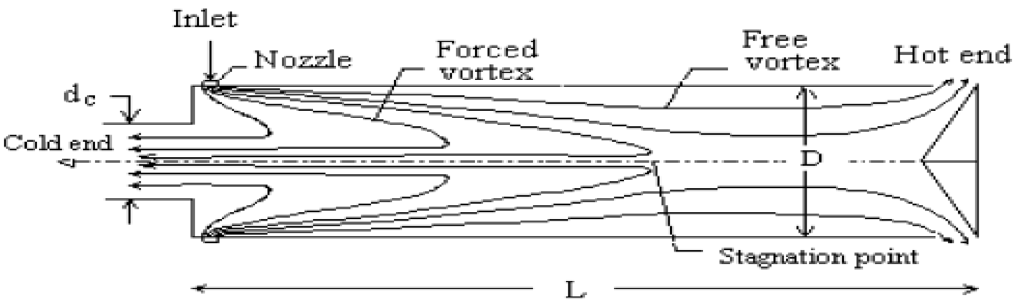


Fig: 2.2 Energy separation of counter flow vortex tube.

The air moves as a free vortex from the nozzle plane towards the valve end. As it reaches near the valve, the kinetic energy is converted into the pressure energy giving a point of stagnation. But the stagnation pressure is higher than the pressure in the nozzle plane; thereby the reversal in flow takes place. This reversed flow comes in contact with the forward moving free vortex, which causes the reversed vortex flow to rotate with it. During the process of forced vortex flow the energy is supplied from the outer moving layer.

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.

III. 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.
In a vortex tube, the outer (hot) air stream is a free vortex. The inner (cold) air stream is a forced vortex. The rotational movement of the forced vortex is controlled by the free vortex (hot air stream). The turbulence of both the hot and cold air streams causes the layers to be locked together in a single, rotational mass. The inner air stream flows through the hollow core of the outer air stream at a slower velocity than the outer air stream. Since the energy is proportional to the square of the velocity, the cold air stream loses its energy by heat transfer. This allows energy to flow from the inner air stream to the outer air stream as heat creating a cold inner air stream.

Present Work

- The effect of material on performance of vortex tube.
- The effect of pressure, length variation on the performance of copper and brass vortex tube.

IV. EXPERIMENTAL SETUP

4.1 Fabrication of Vortex Tube

The vortex tube consists of the following components:

- Main body
- Cold tube
- Hot tube
- Control valve
- Diaphragms
- Nozzle cum chamber

4.2 Main Body

Using the 45mm diameter and length 60mm. internal threats of 14 TPI are cut throughout the length. Figure towards the hot tube side right hand thread is cut and towards cold tube left hand thread is cut.
To provide inlet connection, 18mm hole is drilled and bored to a diameter of 21mm and 14 TPI (Threads per Inch) threads are cut. In order to facilitate convenient holding of inlet tube, shaping is done around the 20mm diameter meter of the main body.

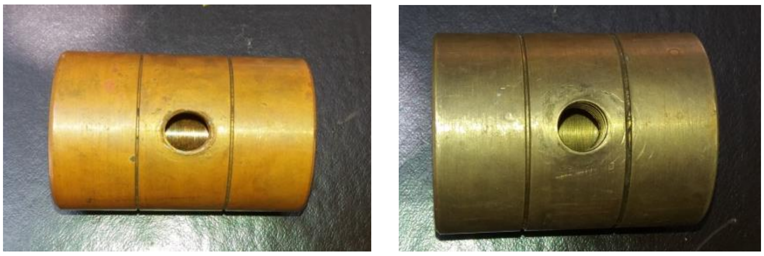


Fig. 4.2.1 Main body (Copper and Brass)

4.3 Cold Tube

Using material of length of 56mm and 25mm diameter meter. 14 TPI threads are cut on the outer periphery of the tube to a length of 25 mm, which is connected to main body. Then 8 mm diameter

meter hole is drilled throughout and bored. After this internal taper turning is done towards the part fixed to main body with small diameter 14 mm and big diameter meter 21mm to the entire length.

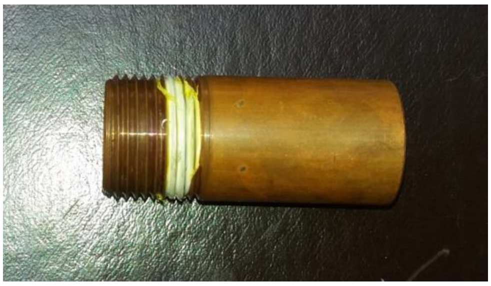


Fig.4.3.1 Cold Copper Tube

4.4Hot Tube

The hot tube is the main component of vortex tube in which the total energy transfer phenomenon is expected to take place. In our present experiment various length of hot tubes are used and the performance is calculated. The various length are 180mm, 165mm, 130mm, 48mm and internal diameter of 16.5mm 14 TPI are made on either side length of 20mm.

Fig 4.4.1 Hot tube

4.5 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.

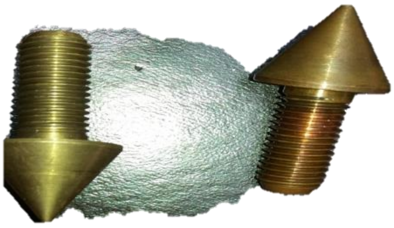


Fig . 4.5.1Control valve

4.6 Diaphragms

A diaphragm is the most important part to be manufactured in the vortex tubes. It is manufactured by using copper and brass material. The material of size 9mm thickness and 25mm diameter. A 8mm diameter hole is drilled and bored.

Fig . 4.6.1 diaphragm (Copper and Brass)

4.7 Nozzle

The nozzle is the key element of the vortex tube which is responsible for tangential entry of the air stream. In this present experiment nozzle having specifications of outer diameter 25mm and a center hole of 16mm is made and tangential hole is drill at the top for air entry into nozzle.

Fig . 4.7.1 nozzle (Copper and Brass)

4.8 Hot End

The materials of a diameter of 44mm and faced to a length of 53mm. 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 9mm diameter are drilled to facilitate the control valve and exit to hot air.

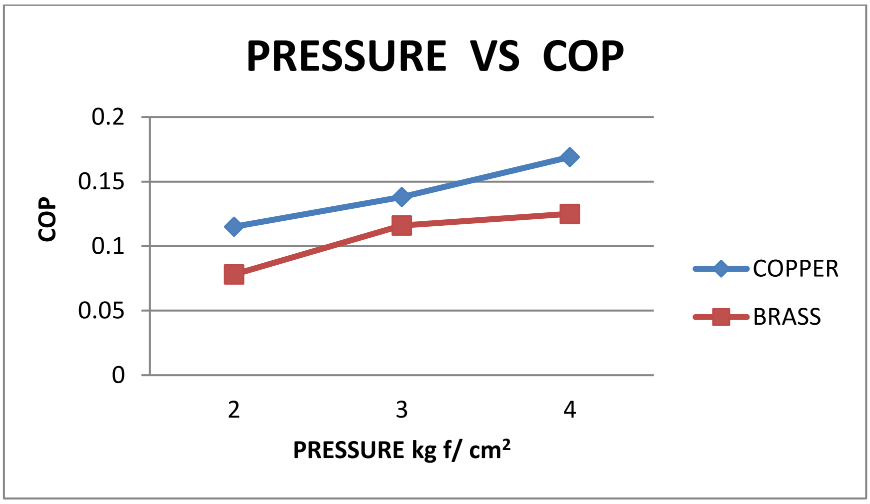
Fig 4.8.1 Hot end (Brass and Copper)

4.9 Vortex Tube Assembly

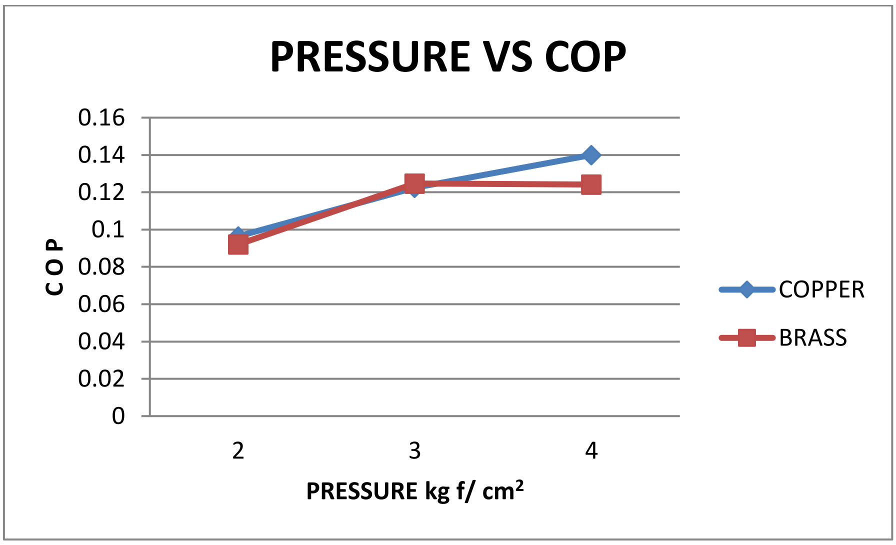
The inlet tube is fixed to the main body, nozzle is inserted into the main body such that both inlet tube and nozzle axis are same. Orifice is inserted into the main body from left side and cold tube is screwed behind the orifice into the main body. Hot tube is screwed into the main body from right side the control valve is inserted into the hot end from one side and at the same side other end of hot tube is fitted to it so that control valve is screwed into the internal threads of hot tube .

Fig. 4.9.1 vortex tube assembly (Copper and Brass)

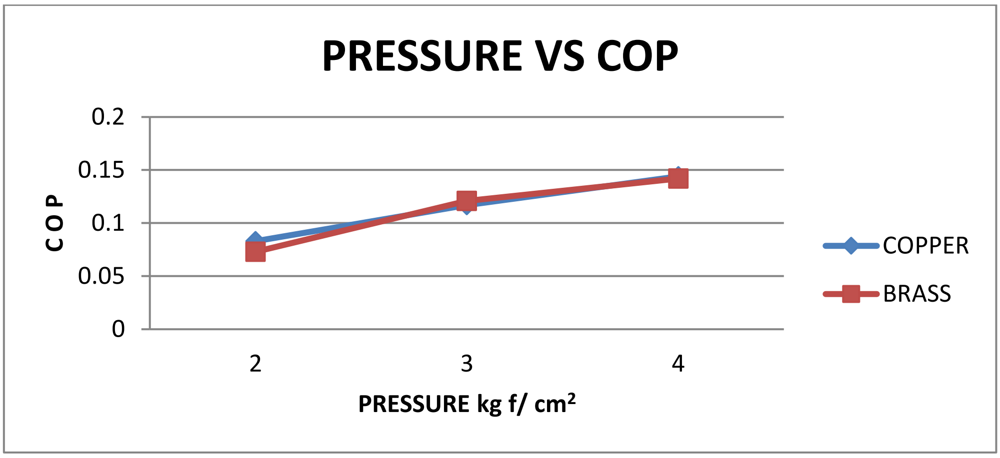
LENGTH (L_1=180mm)



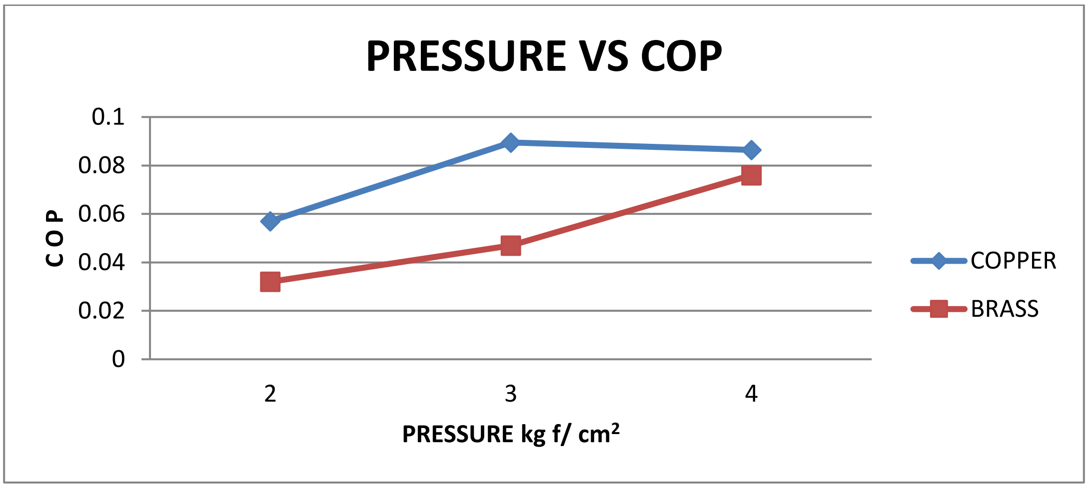
LENGTH(L_2=165mm)



LENGTH(L_3=130mm)



LENGTH(L_4=48mm)



V. RESULT

In vortex tube refrigeration system when copper and brass are used as materials, the co-efficient of performance for copper is better than brass.
The maximum COP for Copper = 1.69
The maximum COP for brass = 0.12

VI. CONCLUSION

The effect of the inlet pressure on the Cold temperature drop, hot temperature raise, and C.O.P of the Vortex tube are analyzed by a steady state condition experiment. The results obtained by this technique have led to the following conclusions.

- The Cold drop temperature ΔT_c increases with increase in inlet air pressure.
- The Hot temperature raise ΔT_h increases with increase in inlet air pressure
- The C.O.P of the vortex tube increases with increase in inlet pressure.
- From the results obtained, it was found that the cop of the vortex tube is copper material is better that the brass.
- From the results obtained, it was found that the decreasing in the length simultaneously decreasing cop of vortex tube.

The graph drawn are showing the effect of increasing the inlet pressure with the temperature drop shows an increase trend i.e. From the above results, it is suggested to have Combination of 160 mm length at pressure 4 kg f/cm^2 of copper material have better performance of Vortex Tube.

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