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Experimental Analysis of Vortex Tube Made of Homogeneous Wood

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***Abstract*: Vortex tube is a device which is capable of separating hot and cold gas stream from an inlet gas stream with a proper pressure .Separating cold and hot streams by using vortex tube can be used in industrial applications such as cooling equipment and refrigerators. This device suits for vital applications because of its light weight, simple and more importantly it is compact. Many researchers have carried out research to identify the factors which affects Vortex tube performance. This paper aims 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 parameters such as the length of VT to its inlet diameter (L/ D) ratio, use of different material in developing the vortex tube and its effect are discussed in detail.**

Key Words: Vortex tube, Wooden, L\D Ratio, Refrigeration,

I. INTRODUCTION

The vortex tube is a thermal static tube that separates compressed gas flow to two streams; one stream colder than the inlet flow while the other stream is hotter than the inlet flow. The vortex tube does not have any moving parts and the separation occurs due to vortex flow generation without requiring any external mechanical work or heat transfer.

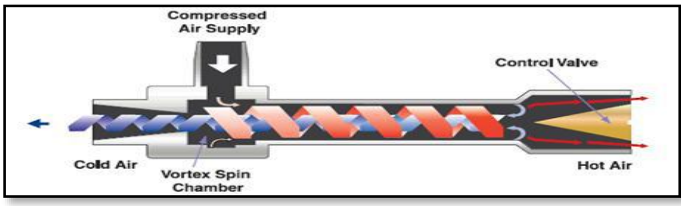

Figure 1: Vortex tube schematic

The vortex tube was first discovered by Ranque [1, 2] who was granted a French patent for the device in 1932, and a United States patent in 1934. Ranque encountered the vortex tube phenomenon while he was experimentally working with vortex tube pump in 1928. In 1945, Rudolf Hilsch [3] conducted an experiment on vortex tube that focused on the thermal performance with different inlet pressure and different geometrical parameters. Gulyaev [4] recommends a minimum length of 13 times more than that of the diameter. Soni and Thompson [5] deduced an L/D greater than 45 for efficient working. Singh P.K and et al [6] states that the effect of nozzle design is more important than the cold orifice design in getting higher temperature drops. Balmer [7] has demonstrated that the heat separation, which occurs inside the Ranque–Hilsch a vortex tube, is not limited to compressible gases and can be applied for non compressible fluids as well. Dincer et al. [8] investigated the effect of control valve tip angle on performance of Ranque-Hilsch vortex tube using different inlet pressures. Behera et al. [9] showed from solutions obtained using computational fluid dynamics that this secondary flow could be related to the cold end cross-sectional area. It was concluded that a secondary flow would occur when the cold end cross-sectional area was small. Dincer et al [10] carried out energy analysis of the vortex tube with regard to nozzle cross sectional area and suggested that the variation of the energy efficiency increased with increasing pressure and cold fraction.

Kun Chang *et.al* [11] performed experimentation with hot divergent tube and found that the Energy separation performance of vortex tube can be improved by using a divergent hot tube. Rahim Shamsoddini*et.al* [12] worked on Effect of number of nozzles on the flow and power of cooling of a vortex tube using a three-dimensional numerical fluid dynamic model. It is observed that as the number of nozzles is increased, power of cooling increases significantly while cold outlet temperature decreases moderately. Nimbalkar et al [13] and Muller (2009) presented the results of a series of experiments focusing on various geometries of the ‘‘cold end side” for different inlet pressures and cold fractions. The experimental results indicated that there is an optimum diameter of cold-end orifice for achieving maximum energy separation. It was observed that for cold fraction less or equal than 60%, the effect of cold end orifice diameter is negligible and above 60% cold fraction it becomes prominent. The results also show that the maximum value of performance factor was always reachable at a 60% cold fraction irrespective of the orifice diameter and the inlet pressure.

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Gurol Onal and Kevser Dincer [14] in this paper, performance of a counter flow Ranque-Hilsch Vortex tube with threads cut on its inner surface was investigated experimentally.

II.EXPERIMENTAL SET UP:

To study the effect of various parameters such as mass flow rates of cold and hot air, nozzle area, cold orifice area, hot end area and L/D ratio on the performance of the vortex tube, an experimental set up was prepared as per design described earlier. The vortex tube components were made in a manner such that the geometry of the tube could be changed from maximum temperature drop tube design to maximum cooling effect tube design. The line diagram of the experimental set up is shown in Figure. The temperature of air at cold and hot ends was measured with digital thermometers with an accuracy of ± 0.1°C. The air velocities were measured made by an anemometer. The pressures were measured by the Bourdon tube pressure gauges. All the instruments were calibrated before the measurements were actually observed/ recorded. Throughout the experiment, the inlet compressed air pressure was maintained at a pressure of 12Kg/cm^2. The operating parameters noted during the experiment for each vortex tube design were:

Air pressure in compressor receiver, --Kg/cm^2
Air pressure near inlet to vortex tube, --Kg/cm^2
Air temperature, ---- ^{o}C
Hot air temperature in------------- ^{o}C
Cold air temperature in------------ ^{o}C

The aim of the experiment is to study the variation of temperature at hot end and cold end with respect to pressure variation and valve position variation.

The parts i.e., inlet tube main body (flange) cold tube, hot tube, Nozzle, Diaphragm, gate value are fitted one by one. The compressor is studied and the pressures are maintained. The settled vortex tube is placed on the table and the outlet of the compressor is attached to the inlet of the apparatus. First the compressor is maintained at a pressure of 8Kg/Cm^2 and the air is allowed to pass through the inlet and have to wait for 5 minutes. After this the thermometers are placed at both the ends and the readings are noted as T_h and T_c. The temperature of air is also noted down by using a Thermometer.

Then the compressor pressure is increased to 10Kg/Cm^2 and the readings are taken in a similar manner. The procedure is followed up to 12 Kg/Cm^2.The readings are tabulated as shown.

After this, the diaphragm of another size is changed to a new nozzle is taken ascend the entire assembly is reset. The experiment is carried out in a similar manner for this nozzle.

III. PROPERTIES OF MATERIALS USED:

S. No	Properties	Sapota wood (Manilkarra Zapotilla)	Rose wood (Dalbergia Latifolia)
1	Average dried weight	65 lbs/ft^3 (1,040 kg/m^3)	52 lbs/ft3 (830 kg/m^3)
2	Specific Gravity (Basic,12% MC)	82, 1.04	70, 0.83
3	Janka Hardness	2,970 lb$_f$ (13,210 N)	2,440 lb$_f$ (10,870 N)
4	Modulus of Rupture	26,710 lb$_f$/in^2 (184.2 MPa)	16,590 lb$_f$/in^2 (114.4 MPa)
5	Elastic Modulus	2,960,000 lb$_f$/in^2 (20.41 GPa)	1,668,000 lbf/in2 (11.50 GPa)
6	Crushing Strength	12,440 lb$_f$/in^2 (85.8 MPa)	8,660 lbf/in2 (59.7 MPa)
7	Shrinkage	Radial: 6.2%, Tangential: 9.2%, Volumetric: 16.0%, T/R Ratio: 1.5	Radial: 2.7%, Tangential: 5.9%, Volumetric: 8.5%, T/R Ratio: 2.2
8	Color/Appearance	: Pink or red to a darker reddish brown or Pale yellowish	Golden brown to a deep purplish brown, with darker brown streaks
9	Grain/Texture	Straight with a medium to fine uniform texture	Medium texture and fairly small pores.
10	Endgrain	Diffuse-porous; medium-small pores	Diffuse-porous; large pores
11	Rot Resistance	Outstanding Durability and Insect Resistance	Very durable and Termite Resistance
12	Workability	Difficult to work on account of its density, Turns and finishes well	Difficult to work with tools because of its interlocked grain and density.
13	Allergies/Toxicity	Severe reactions are quite uncommon.	Severe reactions are somewhat uncommon.
14	Pricing/Availability	Occasionally available, it is moderately priced.	Generally good availability. prices are high
15	Common Uses	Cabinetry, furniture, archery bows and flooring.	Fine furniture, musical instruments, veneer, turned objects.

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IV. MAIN PARTS OF VORTEX TUBE

The vortex tube consists of the following components:

1. Main body 2.Cold tube 3.Hot tube 4.Inlet tube

5. Control valve 6.Diaphragm 7. Nozzle 8.chamber

MAIN BODY:

Fig 2: Main body made of rose wood and sapota wood respectively

COLD TUBE:

Fig 3: A Cold Tube made of Rose wood

HOT TUBE:

Fig 4: Image showing the hot tubes made of rose wood and sapota wood respectively

INLET TUBE:

Fig 5: An image of Inlet tube

CONTROL VALVE:

Fig 6: A Control Valve or Conical needle

DIAPHRAGM:

Fig 7: An image of a diaphragm

NOZZLE:

Fig 8: A Tangential Nozzle made of Sapota wood

V. EXPERIMENTAL ANALASYS:

I.SAPOTA WOOD

Length of the Hot pipe = 290mm Diameter of the hot Pipe = 12mm L/D ratio=24 Room Temperature=36^{0}C

Tabular Column for Sapota wood

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	8	17	21
2	8	6	10	24	28
3	8	6	12	24	31

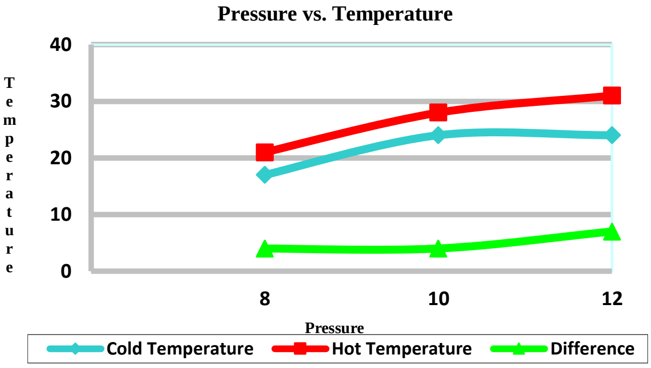

Fig 9: Temperature vs. Pressure analysis of sapota wood VT

II.ROSE WOOD

Length of the Hot pipe = 290mm Diameter of the hot Pipe = 12mm L/D ratio=24 Room Temperature=36^{0}C

Tabular Column for Rose wood

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	8	19	26
2	8	6	10	20	27
3	8	6	12	22	28

Pressure vs. Temperature

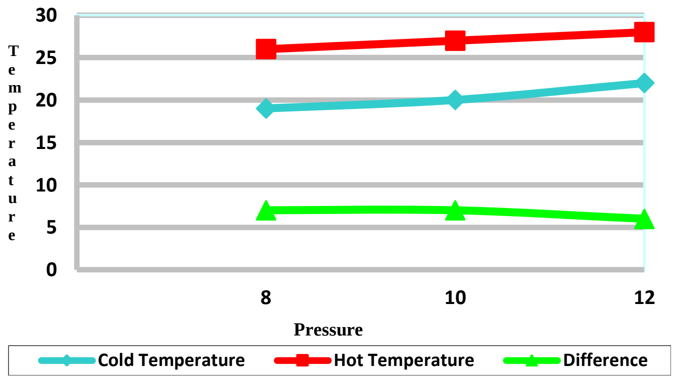

Fig 10: Temperature vs. Pressure analysis of Rose wood VT

Differential Graph between the differences of temperature is further plotted to give a precise understanding of the output achieved between the two distinctive woods used.

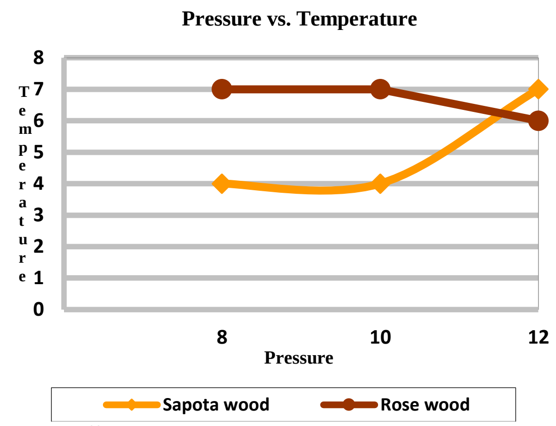

Fig 11: Differences between Temperature gradients attained by the two different woods

VI. RESULTS AND DISSCUSSIONS

We obtained best results when the length (L) 290mm.diameter of the hot tube (D) 12mm and L/D ratio with 24 of both Rose wood and Sapota wood.

After analysis the material of Sapota wood the minimum and maximum température has been obtained 24^0C and 31^0C at a pressure of 12kg/cm^2

After analysis the material of Rose wood the minimum and maximum température has been obtained 22^0C and 28^0C at a pressure of 12kg/cm^2

1. It is clear to that always the performance of vortex tube is directly proportional to inlet compressed air

2. 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 bretter performance so care to be taken while fabrication of the parts to obtain to get good surface finish.

Future Scope

As we all know there are no limits for improvements in any kind of work or we can say nothing is best. There is always scope

for improvements in present work. So, Vortex tube is not an exception. Several investigators have modified the in geometric design of present vortex tube and tested for better performance. But there are still so many options available on which experiments can be done. After some experimental analysis work studied which is done by various researchers, on geometrical modifications for improving the performance of vortex tube are as listed below:

i. We can increase number of inlet air entries.

ii. Experiments are also possible with varying the length of Cold ends and Hot ends.

iii. Same Vortex tube as we have manufactured can be tested by using water as cooling agent.

iv. We can try some modification in the geometry of convergent nozzle with the help of CFD analysis.

v. We can try the same geometry in different material and compare it to find the dependency on material of the vortex Tube.

vi. We can try the non metallic materials like Acrylic, Nylon, PVC, CPCV etc.,

vii. We can try different types of fluids like carbon dioxide, hydrogen as inlet element.

viii. We can try hot tube as spiral with different materials.

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