Vortex Tube for Spot Cooling

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Abstract: In this project, the past investigations of the design criteria of vortex tubes were overviewed and the detailed information was presented on the design of them. Vortex tube were classified and the type of them was described. All criteria of vortex tubes were given in detail using experimental and theoretical results from the past until now. Finally, the criteria on the design of them are summarized and performance of designed vortex tube is evaluated on L/D ratio, cold mass fraction, inlet pressure, nozzle design and no of cut on spinner against temperature difference in hot and cold end.

Keywords – *vortex tube L/D ratio, cold mass fraction, inlet pressure, nozzle, spinner, temperature difference, COP*

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 resource 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. Our aim is have refrigerator and heating oven side by side without spending additional energy.

The Vortex tube (also called the Ranque–Hilsch Vortex tube) is a mechanical device operating as a refrigerating machine without any moving parts. When a high pressure air is tangentially injected into vortex chamber, a strong vortex flow will be created which will be split into two air streams, one hot stream and the other cold stream at its ends. Such a separation of the flow into regions of low and high total temperature is referred to as the temperature (or energy) separation effect.It operates as a refrigerating machine with a simplistic geometry and no moving parts. It can be used commercially in CNC machines, cooling suits, refrigerators, airplanes, etc. Other practical applications include cooling of laboratory equipment, quick start up of steam power generators, natural gas liquefaction, and particle separation in the waste gas industry.The vortex tube has been deployed abroad for spot cooling in the application such as machining, cooling of electronic equipment's, etc. where the quick removal of the intense heat generated is essential.The penetration of these devices in India is rather slow due to non-availability of commercial tubes in the domestic market and prohibitive cost of an imported tube. In this context, an attempt has been made to develop a basic model of cost effective vortex tube and assess its performance under varying operating conditions. If the Vortex Tube is operated continuously for an extended period of time and is set for more than a 28°C drop from the compressed air temperature, the cold end may freeze, blocking the cold outlet. Vortex tubes have lower efficiency than traditional air conditioning equipment. They are commonly used for inexpensive spot cooling, when compressed air is available.However separation in Ranque– Hilsch tubes or the vortex effect, has found wide-spread use in different fields of engineering and technology, e.g., for designing small-flow-rate vortex tubes for individual air conditioners, coolers for automatic-control systems, vortex ejectors, gas-mixture separators,

II. Vortex Tube

The vortex tube is a mechanical device that separates single compressed air stream into cold and hot streams. It consists of nozzle, vortex chamber, separating cold plate, hot valve, hot and cold end tube without any moving parts. In the vortex tube, when works, the compressed gaseous fluid expands in the nozzle, then enters vortex tube tangentially with high speed, by means of whirl, the inlet gas splits in low pressure hot and cold temperature streams, one of which, the peripheral gas, has a higher temperature the initial gas, while the other, the central flow, has a lower temperature. Vortex tube has the following advantages compared to the other commercial refrigeration devices: simple, no moving parts, no electricity or chemicals, small and light weight, low cost, maintenance free, instant cold air, durable, temperature adjustable. Therefore, the vortex tube has application in heating gas, cooling gas, cleaning gas, drying gas, and separating gas mixtures, liquefying natural gas, when compactness, reliability and lower equipment cost are the main factors and the operating efficiency becomes less important.

There Are Two Types of The Vortex Tubes.

1. Counter flow
2. Uni-flow

III.Experimental setup

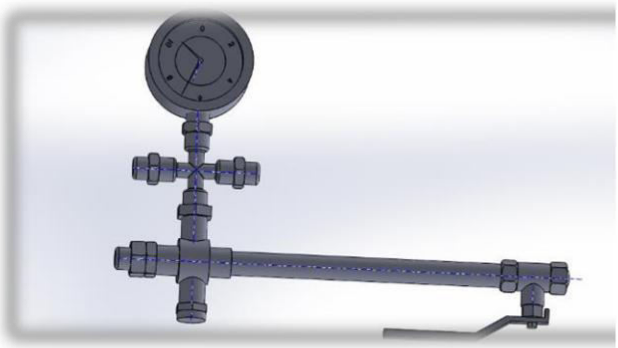


Fig.3 Experimental setup

The experimental setup consists of:

Main body:

It is connecting part of hot tube and cold tube. Length of main body (Figure 4.1) 60mm and diameter is 29mm.The inlet is connected over the main body. The material of this part is PVC and mild steel. Cold tube:

It is a smaller than hot tube. Diameter of cold tube (Figure 4.2) is 29mm and length is 80mm.Material of this tube is mild steel or PVC. Hot Tube:

It is main part of the vortex tube. Material of hot1 tube (Figure 4.3) is mild steel or PVC. Diameter of this tube is 29mm and length is 105mm. At the one end of this tube control valve is placed. Inlet tube:

Inlet tube is fitted into main body at the centre. Pipe from compressor connected to inlet tube. Compressed air enters into main body through inlet tube. Spinner:

Spinner is used for passing the high velocity air as a input of the vortex tube. The diameter of the spinner is 9mm. A tangential cut is given to the spinner by using a hacksaw blade.

Length of vortex tube is one of the most important factors that affect its performance.

To increase the performance of vortex tube, we have to maintain its L/D ratio and cold mass fraction.

Nozzle number also effect on its performance, so keep at low.

Improvement vortex tube cooling capacity by reducing hot tube surface temperature.

The parametric study will be carried for:

1. L/D ratio
2. No. of nozzle
3. Inlet air pressure and
4. Material.

IV. DEVELOPMENT OF SPECIMEN

Fig.4.1 Main body

Fig.4.2 Cold tube

Fig.4.3 Hot tube

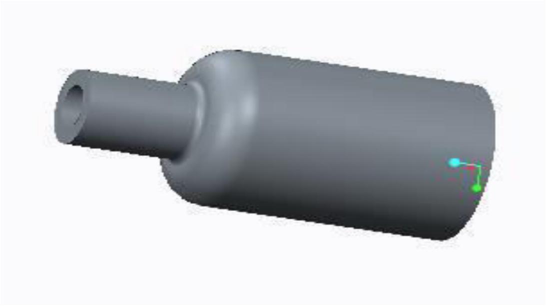


Fig.4.4 Inner tube

Fig.4.5 Spinner

Fig.4.6 Assembly

V. DESIGN OF THE VORTEX TUBE

Vortex Tube Parameters

Performance of a Ranque–Hilsch vortex tube, RHVT tube is mainly depends on the design parameters; geometrical parameters, mass flow, reservoir conditions, gas properties, internal flow parameters, and other factors,

Geometric Parameters

The geometrical design parameters used in the experimentation are listed below

Table 5. Vortex Tube Parameters with Specification.

Parameter	Specification (mm)
Length of tube	160, 240, 320, 400
Diameter of tube (D)	16
Diameter of cold end	16
Diameter of Spinner cuts (Dn)	1
Dn/D	0.06
Number of cuts	3

DESIGN CALCULATION

Shell of the pressure vessel
Types of shell- Thin cylinder

Material of the Shell for design-
The material selected for the shell part of the vessel is SA-106 grade B steel

Factor of safety in the design-
A higher factor of safety is taken because-

As the any unknown force which is not been accounted in the design or which cannot be estimated is taken care of.

After manufacturing of the shell the homogeneity of the material is always a doubt and the material may be weaker at some of the parts.

Failure in service can cause huge losses in terms of property and lives.

Stress concentrations at various cross sections may fail the component.

Higher reliability is achieved.

Also the vessel is operated in a corrosive environment in the given case.

Design failure of shell-

Stresses acting on the shell-

- Tangential or circumferential stress σ_t

$\sigma_t = P_i*D_i/2*t$

- Longitudinal Stresses σ_l

$\sigma_l = P_i*D_i/4*t$

Thickness of shell obtained from formulas:

1. By circumferential stress criteria:-

$$t = \frac{(P_i \times D_i)}{(2 \times \sigma_t \times ή_t)}$$

2. Based on theory of Thin cylinders with modifications:

$$t = \frac{(P_i \times D_i)}{(2 \times \sigma_t \times ή_t) - p_i}$$

VI. CALCULATION:

Cold Air Mass Fraction (∈):

Formula:

$(1)\ (-\ )=$

$\in\ (\ -\ )$

$+ (1-\in)\ (h\ -\ )$

Coefficient of Performance (COP):

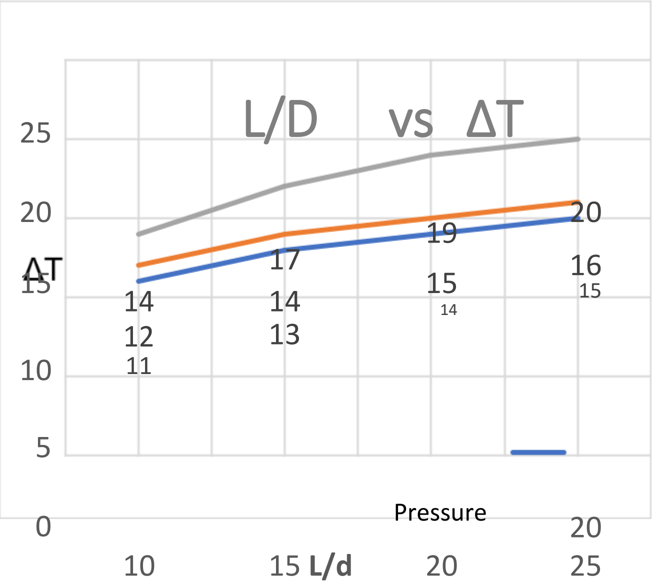
Formula;

$= \frac{}{-1} \times \frac{\in(\ -\ )}{\ln \frac{}{}}$

VII. RESULT TABLE AND GRAPHS:

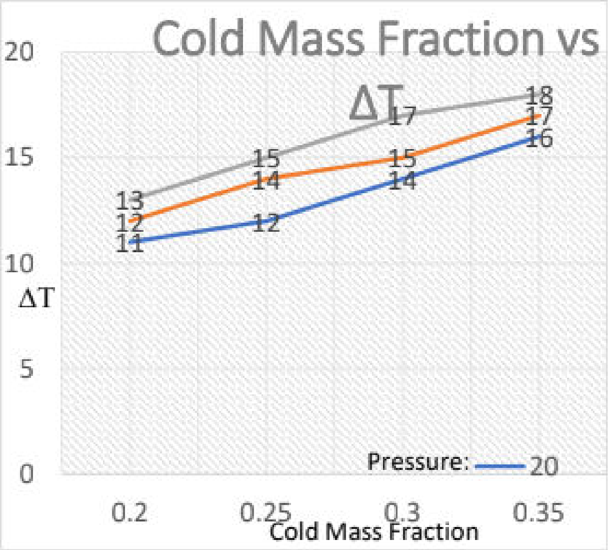
Table 7. Result Table

Observation no.	Inlet pressure (bar)	Cold side temperature (℃)	Hot side temperature (℃)	COP
1	42.5	13	29.5	0.281
2	39	12.8	29.85	0.296
3	37.5	12.6	30	0.306
4	35.5	12.4	30.2	0.318



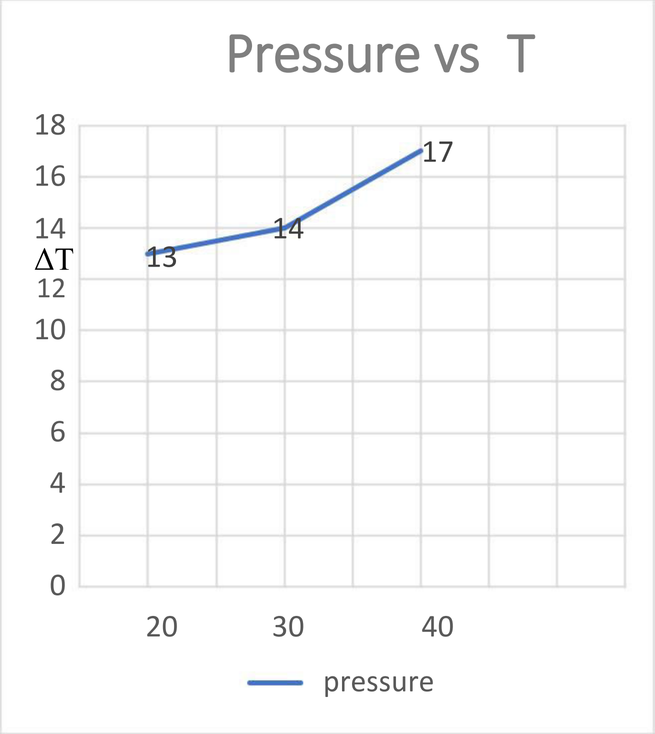
Graph No. 7.1 L/D vs ΔT

ΔT increases with increase in L/D ratio at constant pressure



Graph No.7. 2 Cold Mass Fraction vs ΔT

ΔT increases with increase in cold mass fraction at constant pressure



Graph No.7. 3 Pressure vs ΔT

ΔT increases with increase in inlet pressure.

VIII. PERFORMANCE ANALYSIS

Computation fluid dynamics (CFD)

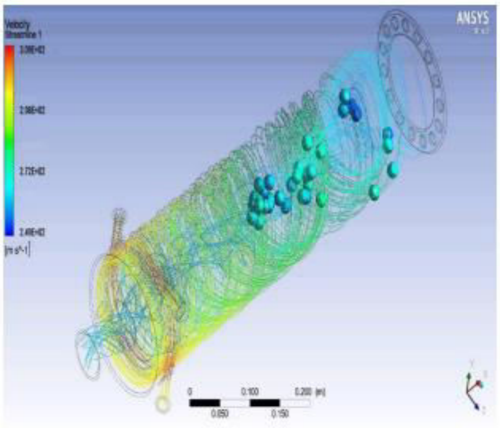


Figure No. 8.1 CFD Analys

Temprature distribution

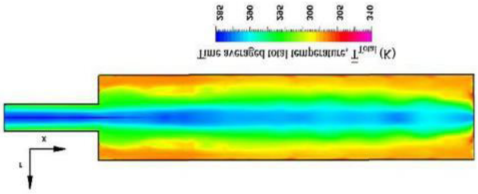


Figure No. 8.2 Temperature Distribution

Fluid velocity profile for six number of cuts

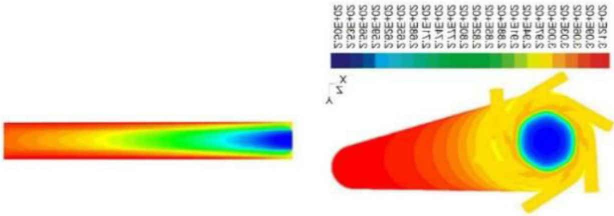


Figure No. 8.3 Analysis for six cut fluid velocity profile

Fluid velocity profile for three spiral cuts

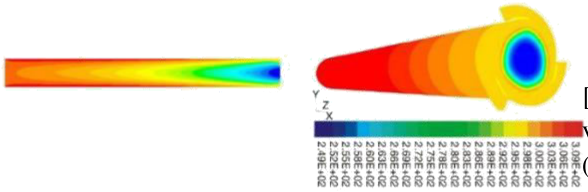


Figure No. 8.4 Analysis for spiral three cut fluid velocity profile

Fluid velocity profile for three tangential cuts

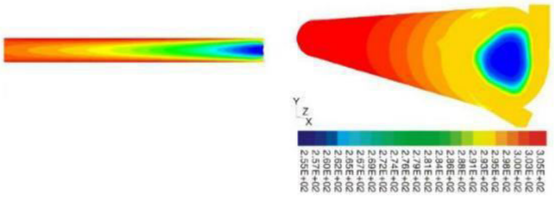


Figure No. 8.5 Analysis for Tangential three cut fluid velocity profile

IX. CONCLUSION:

1. ΔT increases with increase in L/D ratio at constant pressure.
2. ΔT increases with increase in cold mass fraction at constant pressure.
3. ΔT increases with increase in inlet pressure.
4. Velocity profile increases with increase in number of cuts.
5. It is the matter of first importance essential nature of any examination or improvement is its eco-accommodating nature, by the temperance of which it satisfies our fundamental needs with no mischief to the nature. The normally utilized cooling frameworks utilize the gas and fluids which either exhaust the ozone layer or contribute in an unnatural weather change in the same as CO_2 does. Numerous examiners distinguish carbon-dioxide catch and partition as a noteworthy detour in endeavors to cost effectiveness mitigates ozone depleting substance outflows by means of sequestration. Along these lines, vortex tube can be utilized for a spot cooling or spot warming application.

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