DESIGN AND PROTOTYPE OF AIR-COOLED SYSTEM USING VORTEX

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ABSTRACT: The Ranque Hilsch Vortex Tube (RHVT) is a very simple device well known for its phenomenal temperature separation effect. With a single input of compressed gas, the tube simultaneously produces two different streams of gas – one being hotter and other being colder than input gas. The vortex tube is a structurally simple device with no moving parts that is capable of separating a high-pressure flow into two lower pressure flows with different energies, usually manifested as a difference in temperatures. The vortex tube is relatively inefficient as a stand-alone cooling device but it may become an important component of a refrigeration system when employed as an alternative to the conventional throttling valve. Literature review reveals investigations to understand the heat transfer characteristics in a vortex tube with respect to various parameters like cross section area of cold and hot end, nozzle area of inlet compressed air, cold orifice area, hot end area of the tube, and L/D ratio. As such there is no theory so perfect, which gives the satisfactory explanation of the vortex tube phenomenon as explained by various researchers. Therefore, it was thought to perform experimentation. Moreover, the feasibility of improving the cooling performance of vortex tube using the cooling system was investigated. The present numerical results revealed that using the cooling system, the net energy transfer rate from cold inner region to the hot peripheral region increases, thereby improving the cooling performance of the device.

Keywords — Ranque-Hilsch Vortex tube, Temperature Gap, Compressed Air, Mass flow rate, Pressure, L/D ratio, Temperature Separation

INTRODUCTION:

The average temperature of the Earth is rising steadily due to ever increasing pollution and decline of trees as well as forest cover. As a result, the current world demands more effective and intense refrigeration systems that could work satisfactorily under extreme ambient conditions. The conventional refrigeration system such as Vapour Absorption Refrigeration (VAR) and Vapour Compression Refrigeration (VCR) would become rather inefficient and eventually obsolete.

Vortex tube refrigeration is a promising solution to these problems since it provides effective cooling without the use of any refrigerant and thereby eliminating any possibility of effluent discharge or leak. The Vortex Tube Refrigeration is one of the nonconventional types refrigerating systems for producing cooling which is a simple device with no moving parts which could generate cold and hot air/gas streams simultaneously with compressed air/gas as a working fluid. It is essentially an energy separating device which is compact and easy to produce and operate. There are several advantages of using vortex tube for different applications like there is no leakage problem as it uses only air as the refrigerant; no spark and explosion hazard; it is simple in design and needs only control of valves for appropriate functioning as it has no moving parts; light in weight and portable; requires less space; highly reliable; virtually maintenance free; initial cost is low and at places where compressed air is readily available working expenses are also low. However, its low COP and limited capacity hinders its commercial as well as practical applications. By undertaking this project, we aim to develop a practically feasible Vortex Tube Refrigerator and attempt to eliminate all the possible limitations.

As vortex tube does not use any harmful refrigerant, it is an Eco-Friendly component. This Eco-friendly nature and its compactness make Vortex tube to finds application in many fields like cooling the tool and workpiece during machining in CNC and lathe with Using an ordinary supply of compressed air as a power source, vortex tubes create two streams of air, one hot and one cold, with no moving parts with low cost.

OBJECTIVE OF STUDY:

Following are the major objectives that we expect to achieve through this project:

1) To design a vortex tube that provides optimum flow characteristics specifically suitable for refrigeration application.
2) To make an attempt to eliminate the limitations of vortex tube refrigeration namely poor COP and less capacity.
3) To develop a fully functional refrigerator that works on the basis of Vortex principle.

WORKING PRINCIPLE OF VORTEX TUBE:

Compressed air source is connected to vortex tube. The opening is a jet nozzle, which is connected to the compressed air source – Compressor. This jet is arranged to inject the air into the tube at a tangent to the outside circumference of the tube. Due to the design of the jet and the high pressure of the air, the air swirls rapidly around inside the long length of the tube. Two openings are at or near atmospheric pressure. The temperature of the air as it leads through tube will be greatly reduced. Temperature below 0º C is easily obtained with this device [7]. A compressed air is passed through the nozzle. Here air expands and acquires high velocity due to the particular shape of the nozzle. A vortex flow is created in the chamber and air travels in spiral like motion along the periphery of the hot side. The valve restricts this flow. When the pressure of air near the valve is made more than the outside by partly closing the valve a reversed axial flow through the core of hot side starts from high pressure to low-pressure region [7]. During this process energy transfer takes place between reversed stream and forward stream and therefore air stream through the core gets cooled below the initial temperature of the air in the vortex tube. While the air stream in the forward direction gets heated up. The cold stream is escaped through the diaphragm hole into the cold side while hot stream is passed through the opening of valve or orifice. By controlling the opening of the valve (orifice size) the quantity of cold air and its temperature can be varied [7].

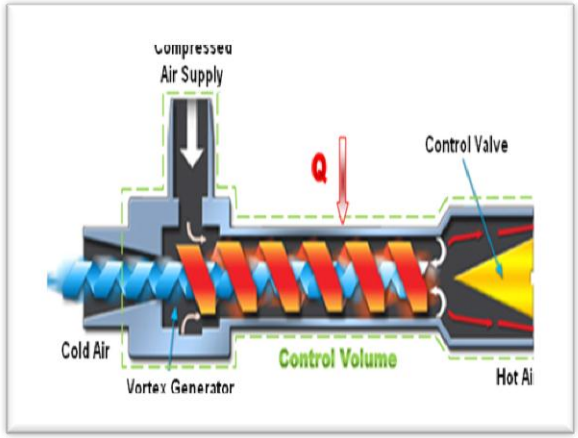


Fig1.1: working principle of vortex tube

DESIGN CRITERIA:

1.) Tube length: The length of the vortex tube affects performance significantly. An efficient tube of either design should be many times longer than its diameter. Optimum L/D is a function of geometrical and operating parameters. The magnitude of the energy separation increases as the length of the vortex tube increases to a critical length, however a further increase of the vortex tube length
beyond the critical length does not improve the energy separation.
2.) Tube diameter: In general, smaller diameter vortex tubes provide more temperature separation than larger diameter ones.
3.) Type and number of nozzles: The inlet nozzle location should be as close as possible to the orifice to yield high tangential velocities near the orifice. For maximum temperature drop the inlet nozzles should be designed so that the flow be tangentially into vortex tube. For maximum temperature drop the inlet nozzles should be designed so that the flow be tangentially into vortex tube.
4.) Cold end diameter: Using a small cold orifice yields higher energy separation while a large cold orifice results lower energy separation in the tube. Coaxial orifices have greater temperature separation in compared to the other orifice configurations such as eccentric orifices, diaphragm nozzles, and diaphragms with cross sections other than cylindrical configurations.

COMPONENTS OF VORTEX TUBE:

Vortex Generator: The Pressurized air is injected into the swirl chamber or vortex generator to form vortex flow of air which strikes on control valve to regulated the flow. We are manufacture a vortex generator with pvc material which is very useful and impactful for cooling purpose.

Compressed air inlet: In Compressed air inlet valve before entering air to vortex generator. The air containing temperature and pressure. There are two and four inlet valves situated at vortex chamber or vortex generator. the inlet valve designed in such way that they are perpendicular and eccentric to the axis of the vortex tube.

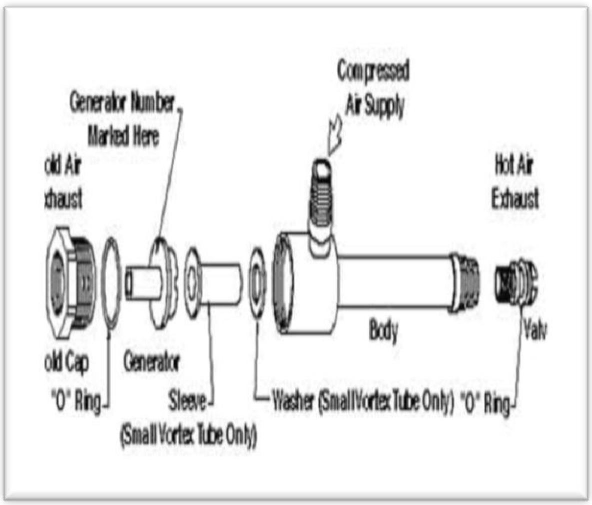


Fig 1.2: parts of vortex tube

Control Valve: The air is controlled by control valve .The flow of air from the inlet valve to vortex generator through the control volume and actual flow of hot air and cold air is mainly controlled by control valve .The control valve consist of regulating knob with adjusting bolt .The conical shape adjuster with different cone angle is attached to the control valve in control volume. The control valve has threads grooved.

Hot air outlet: The compressed air in the vortex tube spines using the vortex generator is spitted into two streams into hot air and cold air. The hot air is ejecting out through the hot air outlet situated at the end of the vortex tube near to the controlled valve.

Cold air outlet: The cold air in which the cold is exit through the cold air outlet. The pressurized air at which is separated among the vortex volume which spin by equated through end near the vortex generator. The cold air outlet is placed to thin and fine exit valve near the vortex chamber.

DIMENSIONS OF PARTS:

S.NO	COMPONENTS	DIMENSIONS
1	Inlet nozzle	Inner diameter: 3mm Outer diameter: 8mm
2	Vortex chamber	Inner diameter :20 mm Outer diameter :38 mm Length:70 mm
3	Hot end tube	Length: 150 mm Outer diameter: 16 mm Inner diameter: 12 mm
4	Cold end tube	Length: 75 mm Outer diameter: 16 mm Inner diameter: 6 mm

Table 1.1: dimension of vortex tube

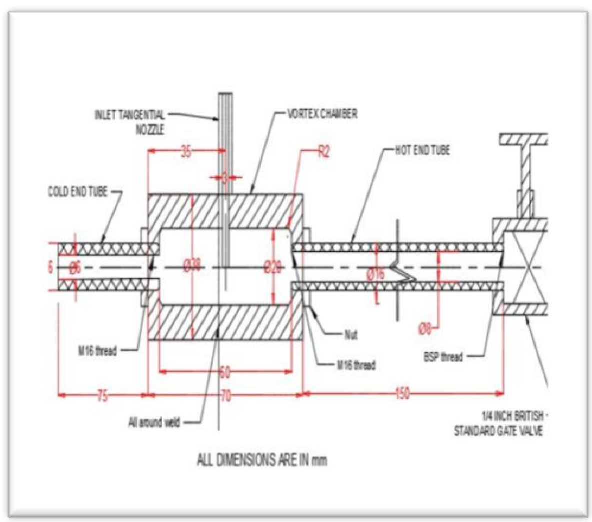


Fig 1.3: 2D representation of vortex tube

OBSERVATION TABLE:

Sr No.	Inlet Pressure	Cold Temp. T_c(°C)	Hot Temp. T_h(°C)
1	4	11.4	31.4
2	6	8.2	34.3
3	8	5	36.8

Table 1.2: temperature of vortex tube at different pressure

CALCULATION:

1) For refrigeration purposes, the temperature at the cold end should be as low as -5°C. (Theoretical)

- Therefore, T_c= -5°C and temperature drop at cold end, ΔT_c= 33 °C
- The Free Air Delivery (FAD) of the Air Compressor Q= 8CFM (cubic foot per minute)

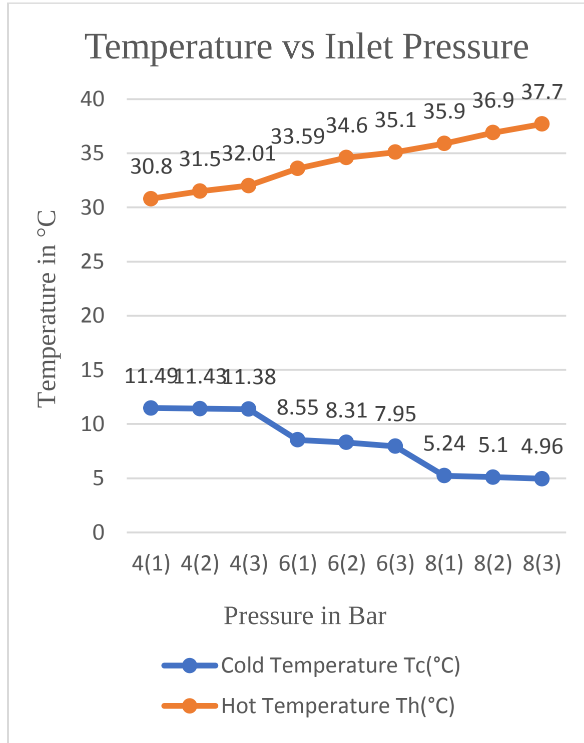
Q = 0.00377 $m3/s$
The mass of compressed air,
m= Q × ρ, where ρ = 10.8 kg/m^3 (Density at 8 bar pressure and 28°C)
= 0.00377 × 10.8
m= 0.0407 kg/ m^3
The Refrigerating Effect,
R.E. = m × Cp × ΔT_c
= 0.0407 × 1.005 × 33
= 1.34981 KW
R.E. = 0.3838 ton

2) From the experimental results, the temperature at the cold end is obtained as

- T_c= 5°C for air compressed at 8 bar pressure.
- The room temperature during experimental conditions, T= 35 °C
- Therefore, The Temperature drop, Δc= 30°C

Free Air Delivery (FAD)= 8, CFM= 0.00377 m^3/s
The mass flow rate, m= Q × ρ, where ρ = 10.8 kg/m^3 (Density at 8 bar pressure and 35°C)
m= 0.00377 × 10.8
= 0.0407 kg/s
The Refrigerating Effect,
R.E. = m × Cp × ΔTc
= 0.0407 × 1.005 × 30
= 1.227 KW
R.E. = 0.348 Ton

GRAPHICAL REPRESENTATION OF EXPERIMENT:



SCOPE OF VORTEX TUBE:

1. Air Suits
2. Vortex Technology and Turbine Fuel Gas Conditioning
3. Vortex Tube Based Refrigeration
4. Vortex Cooling Systems
5. Sub-zero Spot Cooling Using Compressed Air
6. Aviation
7. Personal Air Conditioning
8. Cutting Tools
9. Shrinks Fitting
10. Cooling of Gas Turbine Rotor Blades
11. Laboratory Sample Cooling

CONCLUSION:

It is clear that always the performance of vortex tube is directly proportional to inlet compressed air. The lowest temperature achieved at 8 bar pressure is 5 °C. Placing a tangential nozzle in cylinder is complicated job, this complication can be avoided by Vortex generator. Therefore, we have to select a PVC material for vortex generator and also modify a design. From this experiment we can conclude that the cooling effect of vortex tube is high when inlet pressure is high and when hot cone valve is fully closed. So, we can say that vortex tube's cooling effect also depends on hot cone valve position. We have mad adjustable hot cone valve of better results.

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