VORTEX TUBE – A REVIEW

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Abstract— Vortex tube is considered as a mechanical device which operates as a refrigerating machine. This device separates a compressed gas stream into hot and cold streams. In this paper a series of experiments has been carried out to investigate the influence of uniform curvature of main tube on the performance of the vortex tube. The Ranque-Hilsch vortex tube has been used for many decades in various engineering applications.

Because of its compact design and little maintenance requirements, it is very popular in heating and cooling processes. Despite its simple geometry, the mechanism that produces the temperature separation inside the tube is fairly complicated.

A number of observations and theories have been explored by different investigators concerning this phenomenon. This report goes over some of the major conclusions found from experimental and numerical studies since the vortex tube's invention. One of these studies showed that acoustic streaming caused by vortex whistle plays a large part in the Ranque-Hilsch. In addition, thermal and kinetic energy considerations have been used to explain temperature separation.

Keywords—vortex; stream; temperature separation; kinetic energy;

I. INTRODUCTION

The vortex tube is a mechanical device that separates compressed air into an outward radial high temperature region and an inner lower one. It operates as a refrigerating machine with a simplistic geometry and no moving parts. It is 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. [1]

Vortex tube is a mechanical device that operates as a refrigerating machine. This device separates a compressed gas stream into hot and cold streams. In this paper a series of experiments has been carried out to investigate the influence of uniform curvature of main tube on the performance of the vortex tube. Results show that the curvature in the main tube has different effects on the performance of the vortex tube depending on inlet pressure and cold mass ratio. [2]

Refrigeration

The job of a refrigeration plant is to cool articles or substances down to, and maintain them at a temperature lower than the ambient temperature. Refrigeration can be defined as a process that removes heat. The oldest and most well-known among refrigerants are ice, water, and air. In the beginning, the sole purpose was to conserve food. The Chinese were the first to find out that ice increased the life and improved the taste of drinks and for centuries Eskimos have conserved food by freezing it [3].

The first mechanical refrigerators for the production of ice appeared around the year 1860. In 1880 the first ammonia compressors and insulated cold stores were put into use in the USA. [4] Electricity began to play a part at the beginning of this century and mechanical refrigeration plants became common in some fields: e.g. breweries, slaughter-houses, fishery, and ice production.

Many analysts identify carbon dioxide (CO2) capture and separation as major roadblock in efforts to cost effectively mitigate greenhouse gas emissions via sequestration. An assessment 4 conducted by the International Energy Agency (IEA) Greenhouse Gas Research and Development Program cited separation costs from $35 to $264 per tone of CO2 avoided for a conventional coal fired power plant utilizing existing capture technologies. [3]

Because these costs equate to a greater than 40% increase in current power generation rates, it appears obvious that a significant improvement in CO2 separation technology is required if a negative impact on the world economy is to be avoided. The improvement of current separation technologies is one possible solution to this dilemma. According to the IEA study, chemical or physical absorption technologies possess the highest near term potential for the low-cost and effective separation of dilute CO2 from mixed gases. In practice, this technology utilizes a basic two step process design; first, multi-tray gas-liquid scrubbers affect CO2 removal via absorption to a liquid phase or solvent; and second, liquid absorbent is regenerated by heating, pressure reduction or both. Capture efficiency is predicated largely on liquid circulation rate and gas residence time 5 Under the best of conditions, conventional towers operate at 80% of the equilibrium absorbent loading capacity. [4]

Historical Background

The vortex tube was invented by a French physicist named Georges J. Ranque in 1931 when he was studying processes in a dust separated cyclone. [5] It was highly unpopular during its conception because of its apparent in efficiency.

The patent and idea was abandoned for several years until 1947, when a German engineer Rudolf Hilsch modified the design of the tube. [6] Since then, many researchers have tried to and ways to optimize its efficiency. Until today, there is no single theory that explains the radial temperature separation [7].

There have been many attempted explanations for this radial temperature separation. Two early theories are acoustic streaming and the conversion of kinetic energy into heat. Among recent researchers, turbulence has become a trendy topic. A.F. Gutsol attested that a popular, but complicated theory among specialists is that the separation is explained by turbulent pulsations in the radial direction. In addition, Gutsol introduced the idea of turbulent element rotation. He said that the cause of energy separation is the centrifugal separation of turbulent elements in tangential velocity [1].

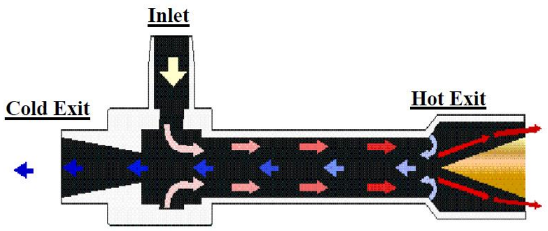

Fig. 1 Ranque-Hilsch vortex tube

Types of Vortex Tubes

There are two classifications of the vortex tube. Both of these are currently in use in the industry [8]. The more popular is the counter flow vortex tube (Fig. 2). The hot air that exits from the far side of the tube is controlled by the cone valve. The cold air exits through an orifice next to the inlet [1].

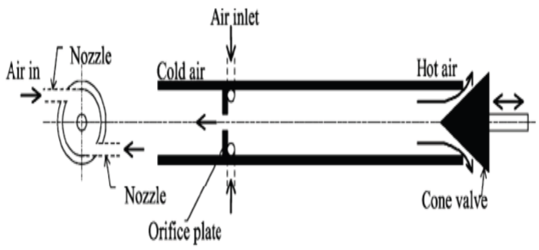

Fig. 2 Counter flow vortex tube

On the other hand, the uni-flow vortex tube does not have its cold air orifice next to the inlet (Fig. 3). Instead, the cold air comes out through a concentrically located annular exit in the cold valve. This type of vortex tube is used in applications where space and equipment cost are of high importance. The mechanism for the uni flow tube is similar to the counter flow tube. A radial temperature separation is still induced inside, but the efficiency of the unit flow tube is generally less than that of the counter-own tube [1].

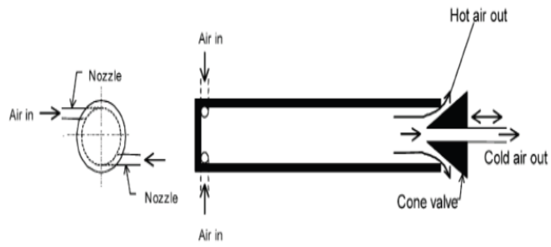

Fig. 3 Unit-flow vortex tube

II LITERATURE SURVEY

Vortex tube is a mechanical device that operates as a refrigerating machine. This device separates a compressed gas stream into hot and cold streams. In this paper a series of experiments has been carried out to investigate the influence of uniform curvature of main tube on the performance of the vortex tube. Results show that the curvature in the main tube has different effects on the performance of the vortex tube depending on inlet pressure and cold mass ratio. [2]

The present paper shows a numerical study concerned with the geometrical optimization of a vortex tube device by means of Constructed Design for several inlet stagnation pressures. In the present study, it is evaluated a vortex tube with two-dimensional axis Symmetric computational domain with dry air as the working fluid. The compressible and turbulent flows are numerically solved with the commercial CFD package FLUENT, which is based on the Finite Volume Method. The turbulence is tackled with the k-ε model into the Reynolds Averaged Navier-Stokes (RANS) approach. The geometry has one global restriction, the total volume of the cylindrical tube, and four degrees of freedom:

The degree of freedom L2/L will be represented here by the cold mass fraction (yc). In the present work it is optimized the degrees of freedom yc and d3/D while the other degrees of freedom and the global restriction are kept fixed. The purpose here is to maximize the amount of energy extracted from the cold region (cooling effect) for several geometries, as well as, investigate the influence of the inlet stagnation pressure over the optimal geometries. Results showed an increase of the twice maximized cooling heat transfer rate of nearly 330 % from 300 kPa to 700 kPa. Moreover, the optimization showed a higher dependence. [9]

The temperature separation effect, which is well known from standard vortex tubes that are driven by compressed air, has been observed in a device where air is sucked into the tube by applying vacuum at the hot and the cold exit ports. Rather than depending on the absolute inlet pressure, the temperature separation was found to be a linear function of the normalized pressure drop X = .p0 −pc /=p0 between the inlet and the cold end of the vortex tube. [6]

This work has been carried out in order to provide an understanding of the physical behaviors of the flow variation of pressure and temperature in a vortex tube. A computational fluid dynamics model is used to predict the flow fields and the associated temperature separation within a Ranque–Hilsch vortex tube. The CFD model is a steady axis symmetric model (with swirl) that utilizes the standard k- turbulence model. The second–order numerical schemes, was used to carry out all the computations. Vortex tube with a circumferential inlet stream and an axial (cold) outlet stream and a circumferential (hot) outlet stream was considered. Performance curves (temperature separation versus cold outlet mass fraction) were obtained for a specific vortex tube with a given inlet mass flow rate. Simulations have been carried. [8]

4. VORTEX TUBE

Working

Based upon the above discussion, this work seeks to design a new absorber that utilizes a variable orifice jet to achieve high mass transfer efficiencies while minimizing energy requirements [7]. This work also seeks to optimize the nozzle type and geometry towards this same goal. The design targets a tenfold improvement in mass transfer efficiency over conventional packed bed technology [6].

Finally, the design aims to package these features into a compact, operationally robust device that is a self-contained gas-liquid contactor and separator. In what follows, the specific features of a vortex tube contactor will be enumerated. [10]

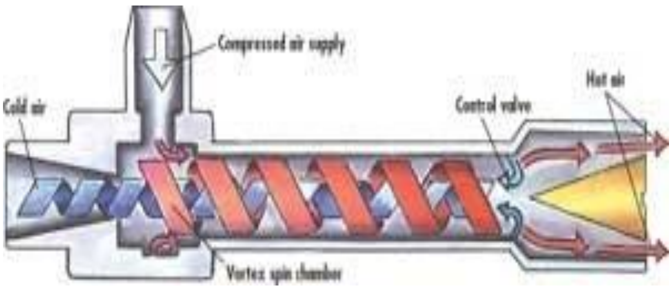

Fig. 4 Actual working

Considered air as working fluid and a compressor which is connected to the reservoir tanks is used to provide the inlet high pressure stream. Volume flow rate and pressure of inlet stream are controlled by regulating valves 3 and 4. A dryer filter 5 issued to trap the moisture content of inlet flow. Thermometer 6 and pressure gauge 7 measure the temperature and pressure of inlet flow respectively. Pressure gauge 16 and thermometer 12 evaluate cold flow pressure and temperature respectively. Temperature and pressure of hot flow are measured by thermometer 14 and pressure gauge 17 respectively. [6]

Volume flow rate of cold and hot streams is determined by two rotameters 13 and 15 respectively. High pressure inlet flow is directed to the main pipe by two tangential nozzles such that vortex flow Is generated. The vortex generator and the configuration of tangential inlet nozzle which are illustrated [2].

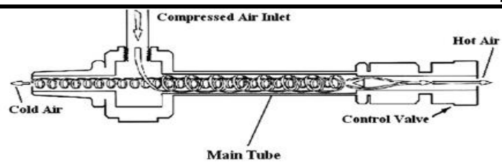

Fig. 5 Cross Sectional view

Diameter of cold flow orifice is selected like dc ¼ 0.5D, this has been proposed as optimum diameter (Saidiand Valipour, 2003), and it is similar among all three vortex tubes. A conical valve which is also similar in all three vortex tubes is used for hot flow regulations demonstrated in fig similarly for all three vortex tubes. The main pipe and cold flow orifice are fitted to the vortex generator at section 3 and section 2 respectively as indicated in Fig. 3. The main tube is made of copper with different turning angle and curvature radius for all vortex tubes, however the axial curvature is uniform (see Fig. 4). For each tube, Inner surface is perfectly smooth and their inner diameters are kept completely constant. Length (L) and inside diameter (D) of main tubes are the same for all three vortex tubes; however their curvature radiuses and their turning angles are different as indicated in diag.

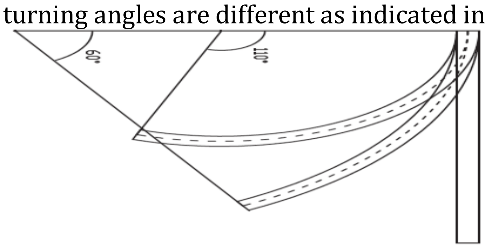

Fig. 6 Geometries of main pipe (curved and straight)vortex tubes.

Compressed Air Supply

Air lines are plagued with condensed water vapor, oil or oil vapor in the air lines. This condensation leads to rust and debris in the air lines. Small orifices in the Arizona Vortex Tube may become clogged with rust, dirt, and water droplets from these unfiltered air supplies.

A 5-micron filter will separate 99% of the foreign matter from the air supply, allowing virtually maintenance free operation. The use of an oil filter with an effective filtration of 0.01 ppm will remove the oil droplets for an even cleaner air supply. Air filter part # 90000 can be used with all Arizona Vortex Tubes and other applied models. The Oil coalescing filter part # 90020 can be used along with the air filter for all Arizona Vortex Tube Products.

Keep in mind that the current line or air hose might contain dirt or oil and should be blown out before installation. Also, pipe thread sealant or tape must be carefully applied to avoid clogging product orifices.

Using Vortex Tube - Generators

The Arizona Vortex generator determines the volume of air through the Vortex Tube. The generator is an internal plastic part already installed in the Vortex Tube. These generators are rated for 8, 10, 15, 25, and 35 scfm at 80 psig. To ensure that your air compressor can generate these volumes, the horsepower of the compressor can be multiplied by four to determine the capacity. A multiple of 5 can be used on newer compressors.

Applications
1.Cooling electronics circuit.
2.Cooling machining operation.
3.Cooling CCTV camera.
4.Setting hot melts.
5.Cooling soldered part.
6.Cooling gas samples.
7.Electronic components cooling.
8.Cooling heat seals.
9.Cooling environmental chamber.

Advantages
1. NO moving parts.
2. No electricity or chemicals
3. Small, lightweight
4. Low cost
5. Maintenance free
6. Instant cold air
7. Durable
8. Adjustable temperature
9. Interchangeable generator.

III SETUP

The schematic of flexible test rig and measuring equipments which are used in this study are shown in Fig. [11]

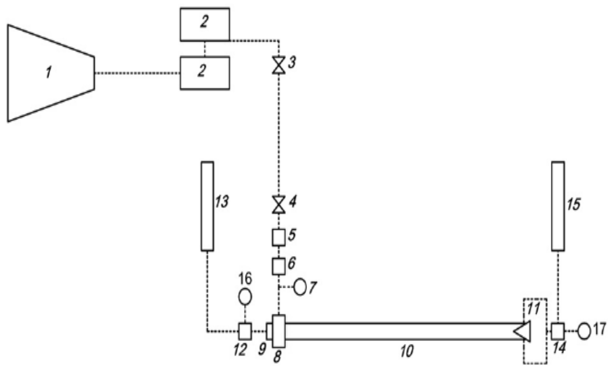

Fig.7 Schematic of test rig and arrangement of measuring equipments

1. Compressor, 2. Reservoir tank
3. Inlet control valve, 4. Regulator,
5. Filter dryer, 6. Inlet thermometer,
7. Inlet pressure gauge, 8. Vortex generator,
9. Cold end orifice, 10. Main tube,
11. Hot end control valve,
12. Cold end thermometer,
13. Cold outlet rotameter,
14. Hot end collector and thermometer,
15. Hot outlet rotameter,
16. Cold outlet pressure gauge,
17. Hot outlet pressure gauge.

Air is considered as working fluid and a compressor which is connected to the reservoir tanks is used to provide the inlet high pressure stream. [11] Volume flow rate and pressure of inlet stream are controlled by regulating valves 3 and 4. A dryer filter 5 is used to trap the moisture content of inlet flow.

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IV OBSERVATIONS AND SAMPLE RESULT

Test is carried on a tube at ambient temperature of 25 degree Celsius with data table and result table are as follows.

Data table

Sr. No.	Hole size	No of Holes	Length of hot end
1	4 mm	1	105 mm
			85 mm
			65 mm

Table 1 Data Table

Result Table

Sr. No.	Hole size	No. of Holes	Hot End Temp.	Cold End Temp.	Temp. Diff.
1	4 mm	1	29	9	20
			30	5	25
			26	8	18

Table 2 Result Table

Acknowledgment (Heading 5)
With a firm belief that a guide in a project is one who holds the candle in the maze of darkness. We take this opportunity to express our profound gratitude to **Prof. M.P. Nagarkar** who as guider, have enacted the role of a torch in their endeavor.

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