A Review of the Ranque - Hilsch Vortex Tube and Counter flow Tube

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Abstract- As a working fluid, compressed air or gas could be used in the Ranque–Hilsch vortex tube to make cold and hot air or gas streams at the same time. This is because there are no moving parts in the device. How much energy and flow separation happens in a vortex tube is very dependent on things like the shape and number of nozzles, the diameter and length of it, the inlet pressure, the control valve, the diaphragm hole size, and the amount of cold mass that's in the flow at the start. In a vortex tube, there is a lot of energy separation and flow patterns that haven't been explained well by any researcher. A computational study of vortex tube flow and energy separation will help us learn more about the physics and mechanisms involved. Many scientists used computational fluid dynamics to look at the vortex and get a better idea of how the flow separates.

Keywords- vortex tube, counter flow, RHVT etc.

I. INTRODUCTION

Vortex tubes, also known as the Ranque–Hilsch vortex tubes, do not require any moving part or supply energy for separating a source of compressed air into cold and warm air streams. Vortex tubes are green systems without the need of refrigerants which have been used in industrial applications for cooling and heating [1].

The device consists of a simple circular tube, azimuthal nozzle(s) for flow inlet, two outlets for exiting cold and hot streams, and a cone obstacle at one end (Fig. 1).

Pressurized gas is injected tangentially into a swirl chamber and accelerated to a high rate of rotation. The gas then separates into two streams having different temperatures, one flowing along the outer wall (peripheral hot flow), and the other along the axis of the tube (inner cold flow).

1. The Ranque - Hilsch Vortex Tube:

British physicist James Maxwell proposed during the 19th century that if one little daemon could be captured and trained to open and shut a small valve a system might be designed to extract warm and cold water from a single pipe. Only if a rapid (hot) molecule approached it, the demons would open the valve and shut the valve against slow (cold) molecules [2].

This hypothetical gadget may provide a source of warm and cold fluids on demand at ambient temperatures with assistance from Maxwell's devil. Although Maxwell hypothesised, he may be shocked to discover that such an apparatus will become a reality in the following century.

This gadget, whose first name was Maxwell's Demon Tube, eventually became known today as the RHVT. The cross part scheme illustrated in fig. 1-1 shows very clearly that, despite the lack of moving parts or work inputs, the RHVT is really an apparatus that concurrently separates the gas flow into two streams, considerably hotter and cooler than intake temperature.

The main reason for this absence of a traditional energy source is in theory why scholars and fans are so keen in the gadget.

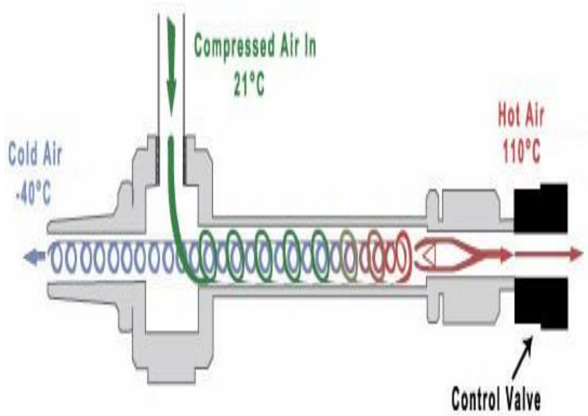

Fig 1. Typical Operation of a Modern Counter-Flow RHVT.

As mentioned above, the genesis of RHVT was acknowledged by the Frenchman Georges Joseph Ranque and the German Rudolf Hilsch, during and after the period of the war in Europe in 1933-1946. They will now explain their contributions.

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2. Ranque's Contribution:

"Soon after, C.D. Fulton [1] published one of the most comprehensive historical articles detailing the chronology of events leading up to and analysis of the RHVT's discovery. When Ranque, the technique's discoverer, appeared before the French Physicist Society in June 1933, he told the general audience that hot and cold air from opposite ends of the pipe was greeted with mistrust.

At the time, aerodynamicists simply concluded that stagnation temperature and static temperature were interchangeable." The image below was taken from the patent of Ranque, along with others in this section.

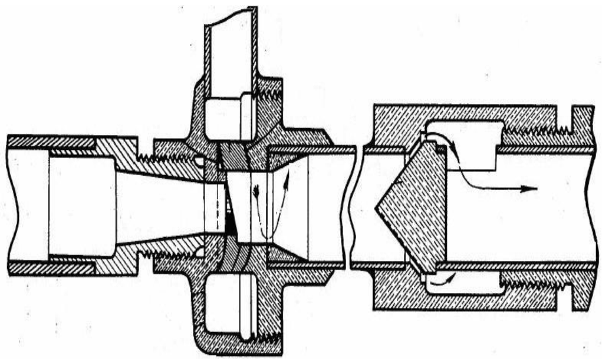

Fig 2. Cross-Section of Ranque's Vortex Tube Design.

Commercial vortex tubes are basically quite similar to those depicted in Fig. 1-2, which is demonstrated by the explosion of the contemporary RHVT in Fig. 1-3, below.

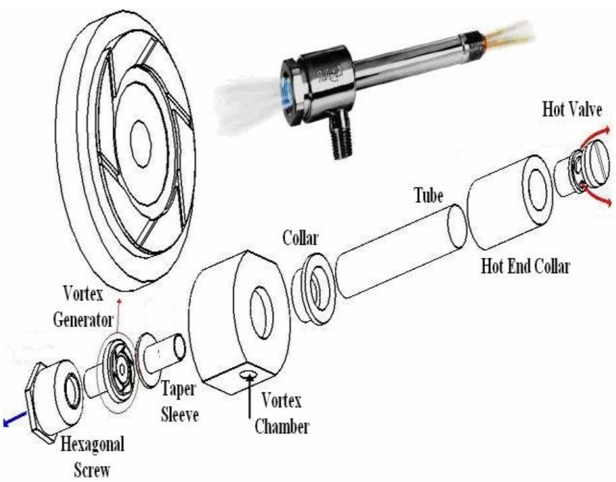

Fig 3. Commercial RHVT by Exair.

"On 12 December 1931 when Ranque submitted a French patent docket, the first public document concerning the RHVT phenomena was published. He filed the identical dockets in the United States after a French patent was granted in 1931 as stated before. In this invention the Ranque demonstrated that a single nozzle, a variety of nozzles or a set of blades may be the tangential entrance. He also described how, by adjusting the size of the cold-air or limiting the end of the hot tube you can achieve a small amount of moderately cold air and said that when the end of the hot tube is completely closed, the colder the cold air will be, the higher the pressure of the air supplies, the higher the cold air. Ranque also spoke about measuring the tyre pressure distribution, a job that is much simpler to say than to perform, as seen in Fig 1.3.

The theory Ranque gives in the United States patent, was stated as follows", "The spinning gas stretches over the wall of the tube in a thick sheet and presses centrifugal force in the inner layers of this sheet, heating them. The inner layers expand and get chilly at the same time.

II. LITERATURE REVIEW

Aswalekar, U. V, et. al. (2014) This article compares energy division into counterflow and uniflow vortex tubes for the same geometric and operational characteristics. This is an experiment that has been conducted. "There will also be a 3-D CFD study to determine the reason of differences in energy separation across various kinds of vortex tubes. The flow range is examined in both tubes and work and heat transfer rates are computed between the core and the perimeter. The tangential rushing work is recognized for the energy separation of the core region into the periphery in both counterflow and uniflow tubes, while the heat transfer from the periphery into the axial area decreases the energy separation".

Bazgir, et. al. (2019) Rankque Hitsh, "The Vortex tube absorbs the gas and it refreshes it. The variables contributing to this decrease include significant expansion, centrifugal strength, secondary circulation and friction. We have developed an air vortex tube for cooling and fluid operation.

The measurements all contain temperature, pressure, discharge, weight, speed and other flux features. Our ideas were placed and gathered on the table. Input pressures were used: 7-6 bar, 6-5 bar, 5-4 bar and 3-4 bar. In the case of CNC machines, spot coolers and other applications, the Vortex tube is utilized as cooling device. Maintenance is quite low since this method does not have any moving components. The aim of this essay is to concentrate on two different geometric features of the vortex tube.

Bej, N. et. al. (2014) This study investigates energy separation, radial variation, and maximum efficiency of the vortex tube using an exergy analysis to determine energy and flow phenomenon separation within the vortex tube. Air is a working fluid or coolant. Many million-dollar vortex tubes (1.2 million, 3.4 million, Valve Angle 300,450,600,900) with various geometrical features were used throughout the procedures.

Cold mass accounts for between 0.1 and 0.9 percent of total mass. The exergy is measured using these factors.

The Exergy has the highest efficiency with a 600 valve angle and a 0.4022 nozzle 4. In order to improve exergy efficiency with different working fluids, L/D ratios, whole diameter, cross-section tube, and valve angle form, further research on the vortex tube is required.

Celik, Aet. al. (2014) Counter-flow heating and cooling are influenced by the cold end of the aperture diameters, the length-to-diameter ratio, and valve output angles. Working liquid for a Ranque-Hilsch vortex tube is air. Brass cold tubes and apertures were used in these tests.

Experiments have demonstrated that increasing the cold tip diameter reduces the loss of exergy between heat and the cold fluid. Energy efficiency decreases when the L/D ratio rises. In a differentiated vortex tube, there is also evidence of reduced exercise loss than in a single tube. The loss of vortex exergy at the hot end is influenced by valve angles.

Dhillon, A. K et. al. (2014) In this study, three RanqueeHilsch vortex tubes with an inner diameter of 9 mm and a length-to-diameter ratio of 15 were used. Their performance was divided into two categories: hot cascading type RHVT and traditional RHVT type RHVT. Performance analysis is difficult due to the temperature differential between the heated exit and the intake (D Thot.).

The Ranquee Hilsch vortex values in the hot-cascade tube were greater than RHVT's D Thot value. The total input exergy, total output exergy, total exergy loss, and efficacy of the hot stream were calculated using experimental data. The total loss of power as a proportion of the cold flow reduced in both conventional RHVT and hot waterfalls. It has also been shown that RHVT is more effective than traditional RHVT heat cascades.

Di Domenico, et. al. (2014) Experimental research is carried out on the dust, intake pressure, and number of intake convergence features. It will study the impact of 1e2.85 nozzle convergence ratios. The main aim of the research is to show how CFD can be used to build a tool that can be used with confidence in a broad array of conditions and geometries and therefore provide a strong tool to optimise the design of vortex tube and assess its use in new applications. The performance of the vortex tube system was predicted by development of a computational dynamics model. FLUENT 6.3.26 was utilised to carry out a complete 3D (3D) CFD simulation.

This model uses the key 3 turbulence model to solve flow equations. Experiments to validate the findings of the simulation have also been performed. The first objective of numerical research was to validate these findings with experimental information and the second objective was to optimise the experimental model for the highest possible performances.

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