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# An Overview of Performance Analysis of Vortex Tube for Different Parameters

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## INFO

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## ABSTRACT

This paper discusses the effect of various paraments of vortex tube on its performance. The vortex tube performance is depends on inlet air pressure, L/D ratio, as it relates to cold mass fraction, inlet pressure and nozzle number, mass flow rates of cold and hot air, nozzle area of inlet compressed air, cold orifice area and hot end area of the tube, different conical valve angles etc. Different researchers consider different paraments to improve cold mass fraction, COP of vortex tube. The purpose of this paper is to present energy seperation phenomena and paramenters which affecting the performance.

**Keywords:** Electrorheology, ER Dampers, Electrorheological Fluid and Zeolite

## Introduction

In 1933 G. J. Ranque (1) introduced a peculiar device wh ich "separates" gases into hot and cold fract ions; he potented it in 1934. His interest lay in its potentialities as a refrigeroting unit, but apparently he was unable to develop it satisfactorily. Nothing more was heard of the device until 1946, when R. Hilsch constructed a number of tubes and published data with respect to their operotion. His work attracted rather widespread interest and, as a result, a number of relevant publications have appeared.

There are 14 fairly obvious variables: tube ma terial, tube thickness, tube length, tube diameter, jet angle, jet diameter, location of jet with respect to the two ends of the tube, gas pressure, gas composition, gas temperature, hot-end baffle, cold end baffle, time of operation and tube temperature which can affect performance of Vortex tube.

The performance of microscale Ranque-Hilsch tubes, nonmoving part pneumatic devices that separate cold fluid from hot fluid for the purpose of cooling, has not received much attention. Traditionally, the vortex tube has been used in many low temperature applications where efficiency is not the most important factor. For example, the vortex tube has been used to cool parts of machines, dehumidify gas samples, cool electronic control enclosures, chill environmental chambers and test temperature sensors. A microscale Ranque-Hilsch tube in combination with a microfluidic pump has potential application in the cooling of electronic chips.

The phenomenon of temperature separation occurring inside a cylindrical tube was reported for the first time by a French physicist by the name of Ranque (1), who applied for a U.S. patent and subsequently presented a paper to the French Society of Physics (3). The discovery was further advanced by Hilsch in 1947 (4) who published some constructional details of the vortex tube along with the performance curves of the device for different tube diameters at various operating conditions. The vortex tube is a very simple device without moving parts i.e., diaphragm, pistons, shafts, etc., as shown in Figure 1. In this arrangement a stream of a compressed gas usually air is injected tangentially into the vortex tube, which has a diameter *D*, using one or more nozzles symmetrically located around the tube. The injected flow accelerates at the entrance, establishing a strong swirl flow, which causes a region of increased pressure near the wall and a region of decreased pressure near the axis.

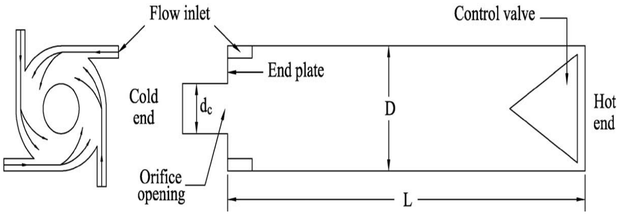

**Figure 1.Vortex tube schematic drawing**

The presence of an end wall alongside the inlet nozzles forces some of the injected gas to flow axially in a helical motion toward the far end of the tube the hot end where a control valve is located. In the usual operation of this device, the flow through the hot end is restricted by partially closing the control valve. This causes even the low pressure at the center of the tube to be higher than atmospheric and hence flow exits the central orifice in the end wall. This also causes some of the flow that had been directed to the far end of the tube to reverse direction along the center of the tube and also to leave the tube through the central orifice. The gas escaping near the tube wall at the far end of the inlet nozzles has a higher stagnation temperature than the incoming gas and the gas exiting through the central orifice has a lower stagnation temperature than the inlet gas.

A very low temperature can be obtained from the cold end by operating the device at a supply pressure of a few atmospheres. For example, Hilsch (4) operated a 9.6 mm diameter tube using compressed air at an inlet pressure of approximately 600 kPa and an inlet temperature of 293 K to produce a cold temperature, $Tc$, of 245 K. The temperatures of the hot and the cold stream are varied by properly changing the cold mass ratio, $\dot{m}c / \dot{m}o$, which can be entirely regulated through the control valve located at the hot exit.

## Literature Review

The Effects of the geometric parameters on vortextube performance have been investigated by many researches, using both experimental and numerical methods. The result has been obtained that, when different geometrical parameters were selected for testing a vortex tube,the temperature generated in cold and hot streams can be varied.Geometric parameters which can be varied are as length and diameter of the tube, shape and size of the inlet nozzle, cold and hot exits and structures of the tube.

**Tube Length:** The effects of the tube length tube diameter and ratio of the tube length over tube. Diameter is summarized and it has been reported that the length of the tube should be longer than a critical length to achieve significant temperature separation within the vortex tube.

The separating vorticities betweenmulti-circulation region and the cold core becomes weaker when the vortex tube is shorter than the critical valueand from the multi-circulation regionthe cold flow will subsequently mix with the hot flow. Hence, the temperature separation in very short vortex tube will not be significant.It is noted that the length of the tube denotes the separation of cold region and hot region. Thus it alwaysthe quality of separating temperature. The vortex tube'scritical length is different for different tube diameters.

**Tube diameter:** The performance of a vortex tube depends on the function of the tube diameter when it isoptimized. A perfect separation of the cold and hot regions provided by the diameter of vortex tube, which dictates the performance for the temperature separation. The temperature drop is reduced because of the diameter of the vortex tube is too small or too large. At the hot end, peak multi-circulation will be found in a vortex tube with large diameter, due to its small centrifugal force. Therefore, for a vortex tube with fixed length, there is a critical value of the tube diameter for the generation of maximum, temperature separation.

**Ratio of tube length over diameter:** In order to have significant temperature separation in vortex tube, the ratio of the tube length over diameter needs to begreater than 20. Once the ratio is greater than 45, it was reported that there is no further effect on the performance of the vortex tube. This is likely due to the fact that the cold core region and the multi-circulation region have been fully separated when the ratio of the length over diameter is 45. Therefore, it does not apparent that further lengthening of the vortex tube has any influence on the vortex tube performance. The increase and decrease in the tube length and tangential velocity respectively results to a slight change in the temperature drop of the stream by weakening the multi-circulation region has been observed .

**Tube shape:** It has been reported that a conical vortex tube can generate two streams whichexhibit significant temperature differences. Optimum conical angle has been proposed by several researchers. However, there has not been an explanation for the apparent successful application of the conical tube in shortening the length of the vortex tube. According to the abovementioned explanation, the separation of the cold core region and the multi-circulation region, in short conical vortex tube, still can be successfully achieved. Due to the conical angle of the tube, the formed, multi-circulation region in the rear part portion of the tube, which makes the radial dimension at the end of the multi-circulation 9 away from the hot end), increase. Hence, the mixture of an enlarged multi-circulation and the cold region can be neglected. Thus, a short conical vortex tube still perform well with regard to the extent of the temperatureseparation.

**Vortex angle:** A new geometrical parameter, termed the vortex angle, has been investigated. It has been reported that the introduced vortex angle had effects on the magnitude of the temperature differential achieved. Based on the proposed explanation, the introduced vortex angle leads to a decrease of the tangential velocity and an increase in the axial velocity. Since both the temperature drop and temperature rise are produced by the strong swirling flow, the decrease of the tangential velocity is the reason for the reducing the temperature parting in a vortex tube with a vortex angle generator installed.

**Inlet nozzle:** The strong swirling flow, which is the reason for the temperature parting in thevortex tube, is generated by the injected maximum speed fluid through the inlet nozzle. Therefore, the inlet nozzle, which shows good characteristics in creating the swirling flow, is the primary instrument in creating the two streams which result in large temperature difference within the vortex tube. The dimension of inlet nozzle doesn`t exceed a critical value, in order to generate the strong swirling flow. Generally, an increase in the inlet nozzle number leads to greater injected flow and same flow in the tube, both of which lead to impressed temperature separation. Furthermore, too many inlet nozzles will cause a high back pressure inside the tube and lead to a decrease of the swirl velocity results in a reduction of the temperature separation. These is discussionsregarding the inlet nozzle with the results presented.

**Effect of conical valve angles on cold temperature:** The effect of conical valve angles and orifice diameter on cold end temperature. For5,6 and 7mm orifice diameters and valves 300,450,600,900 angles. The results depicted in state that the performance of 45o conical valves angles is best for highest supply pressure of 5bars and with orifice diameter as 7mmm; the temperature observed is 50C on cold end side. Performance of 900 valves is also comparable to that of 450 conical valves it also comparable to that of 45 conical valves is also produces the low temperature on cold end. The 30 and 60 degrees conical valve performance is not much expected. With change in valve angles the flow is guided and when valve angle is 45 degree the reversal of flow is smooth and as the orifice diameter increases chances of secondary circulation are minimized hence there is no mixing of the hot stream and cold stream. The velocity along the axis increases because of convergent section and provides potential for the heat transfer among the hot stream and cold stream. The results also shows that the mass of air releasing out from the hot end is minimum. If the pressure is held constant, changes in valve angles shows change in temperature in the descending sequence of 60,30,90,45 degrees. Thus valve angle has effect on the energy separation. Almost 15 to 25% changes are observed with increasing valve angle from 30 to 45 degrees. The COP of vortex tube is usually very low but with converging type of vortex tube the efficiency is seen to be increased. The COP of the vortex tube primary depends on the cold mass of air and the cold end temperature produced. In case of converging type of tube low both mass flow rate of the cold air and the temperature drop are significant hence for majority of the cases as pressure increases the COP of the tube increase and for the orifice diameter of 7mm highest COP is observed for 45 degree valve.

## Various Parameters Influencing Vortex Tube Performance

### L/D ratios

*N. Agrawal et al,* in their experimental work examined three different single nozzle vortex tubes of the length 125 mm,175 mm and 225 mm also L/D ratio of 12.5, 17.5 and 22.5 with tube diameter as 10 mm and inlet nozzle diameter as 2 mm. Inlet pressure is also varied with increment of 1 bar from 3 to 5 bar. For the testing, cold mass fraction is varied with step size of 10% from10 to 90%. At 4 bar pressure, It can be seen that for each L/D ratio, initially cold end temperature drop increases to maximum at an optimum value of cold mass fraction of 60%.Maximumvalue of cold end temperature drop of 29 °C is obtained for L/D ratio 17.5 at 60% cold mass fraction while with L/D ratio of 12.5 and 22.5, maximum cold end temperature drop values are about 26 °C and 24 °C, respectively. This may due to incomplete separation of the cold air and hot air streams beyond a certain L/D ratio for a specific vortex tube, cold stream mixes with hot stream resulting drop in cold end temperature drop.

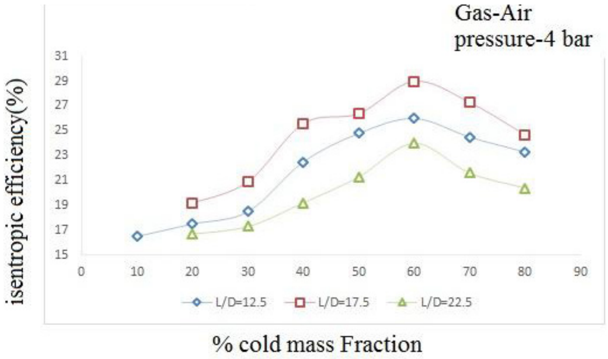

**Figure 2.Variation of cold end temperature drop with cold mass fraction at various L/D ratios**

### Orifice Diameter

Similarly, by varying the cold orifice Diameter [DC] as in diameter of 3mm, 4mm, 5mm vortex tubes, When experimenting pressure at 3 bar, highest temperature drop is obtained with cold orifice diameter of 4 mm and the maximum cold temperature drop obtained for cold orifice diameter 3 mm is 23 °C and 5 mm is 24 °C. The orifice diameter is too small, there is a significant pressure drop across the orifice leading to a higher back pressure in the vortex tube resulting in low energy separation.

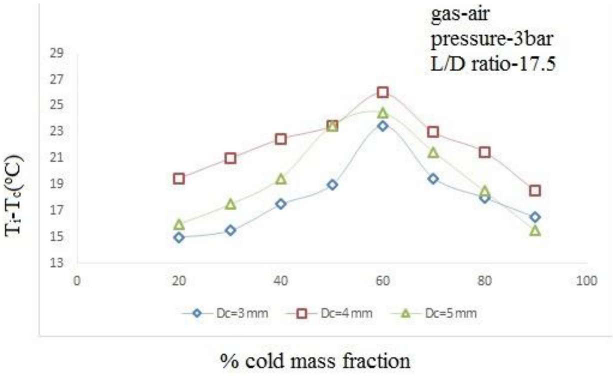

**Figure 3.Variation of cold end temperature drop with cold mass fraction at various L/D ratios**

## Effect of Pressure

On varying the pressure ranging from 3 to 6 bar with increase of 1 bar. It is shown that increasing the inlet pressure increases the cold end temperature drop up to cold mass fraction of 60%. The highest temperature drop measured is 32 °C at the inlet pressure 5 bar while 29 °C and 26 °C temperature drop were obtained at 4 bar and 3 bar pressure supply, respectively. The highest cold end temperature drop at the respective operating pressures is seen at 60% cold mass fraction. This is because mixing of hot and cold mass of working fluid leads to net reductionin cold temperature drop. It is that the cold end temperaturedrop is at the maximum at 5 bar, it can be said that the chosen vortextube of L/D 17.5 is capable of causing full expansion of theworking mediumair at this pressure.

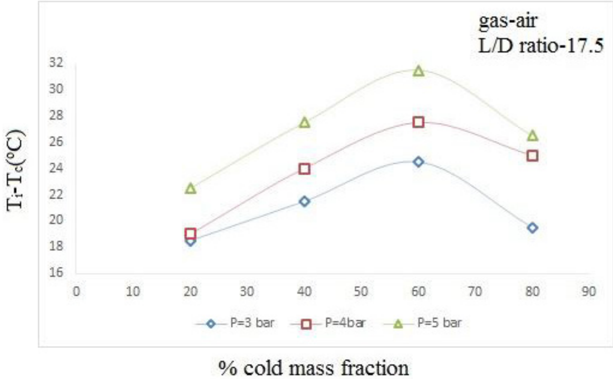

**Figure 4.Effect of pressure on cold end temperature drop**

## Conclusion

Performance evaluation of the Ranque-Hilsch vortex tube has been carried out theoretically. There is a value of cold mass fraction at which vortex tube has the highest temperature drop for all the given pressures at the L/D ratio of 17.5. The maximum cold end temperature drop is obtained at cold mass fraction of 60%. For the given L/D ratio, as the gas pressure increases, cold end temperature difference increases but the optimum value of cold mass fraction remains same. In the tested range, COP and Refrigeration effect increases as the cold mass fraction increases at the pressure of 4 bar and 5 bar. At a pressure of 3 bar the maximum COP and Refrigeration effect is attained at a cold mass fraction of 80%. It is also observed that the cooling effect produced by the vortex tube depends on properties of the gas, molecular weight and specific heat ratio. The vortex tube performs better with carbon dioxide compared to air and nitrogen owing to its high molecular weight and low specific heat ratio.

## Research Gap

As most of work is done on heometrical parameters of vortex tube specially conical shape of hot end valve but no one has done experimental analysis of different shapes rather than Conical also at energy seperation point we can provide convergent and divergent shape for better cold mass fraction.

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