Fabrication and Experimental Analysis on L/D Ratio of Vortex Tube

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Abstract-

Now a days, the first and foremost important quality of any research or development is its eco-friendly nature. As we know, environment safety has become an important aspect of the industries and people in common. Vortex tube is also known as non-conventional cooling device that will produce cold air and hot air when we passed compressed air from compressor without causing any harm to the nature. In vortex tube, when a compressed air from compressor is tangentially passed into vortex chamber a free and forced vortex flow will be generated which will be divide into two air streams i.e. one has lower temperature than inlet temperature and other one has higher temperature than inlet temperature. It can be used for any type of spot cooling application. In this research an attempt is made to fabricate and test a simple vortex tube. The effect of change in length and diameter of vortex tube i.e. (L/D) ratio is investigated and presented in this paper.

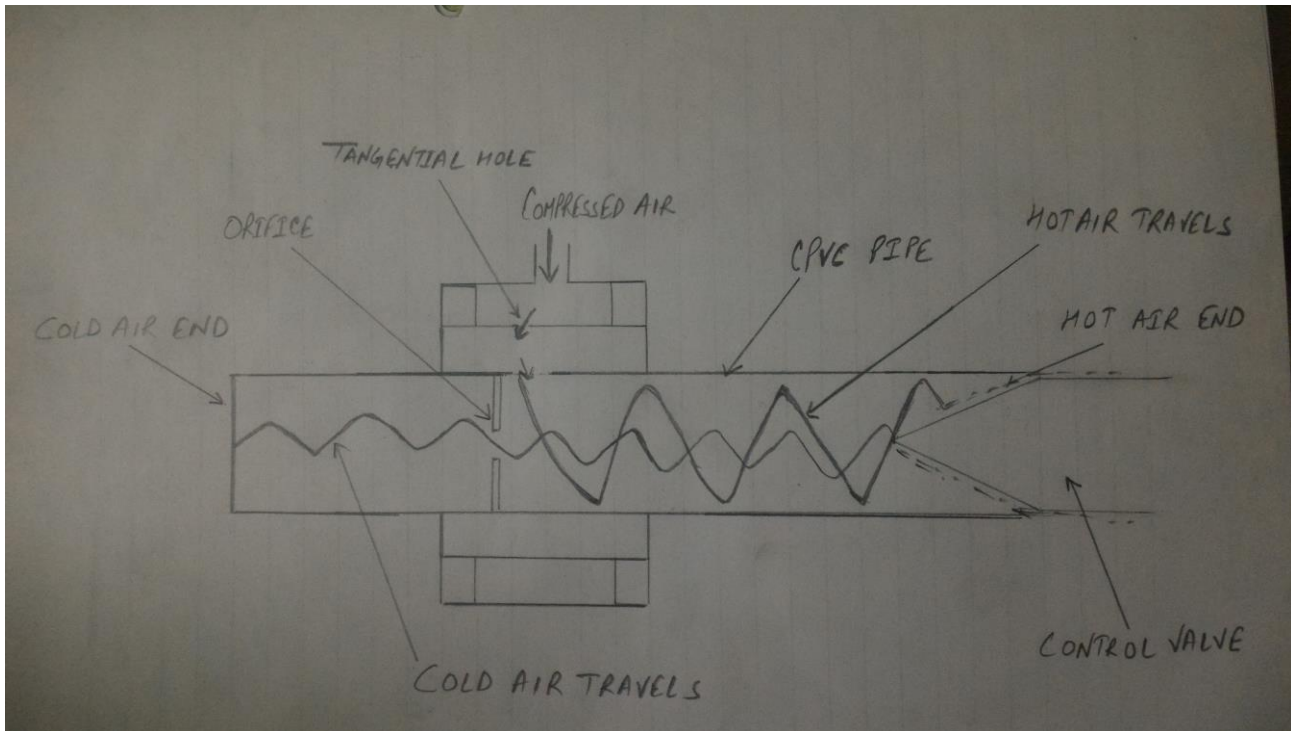Keywords- Vortex tube; orifice; inlet pressure; tangential nozzle.

I. INTRODUCTION

General refrigeration systems use very harmful refrigerants, as they are the major cause for depleting ozone layer. Major research work is focussing on to eliminate the use of very harmful refrigerant but side by side we are focussing on their efficiency or c.o.p.

The vortex tube is also known as non-conventional cooling device which was invented by scientist named RANQUE so it is also called as ranque tube, which is a remarkably a simple device, reliable and produces 2 air stream i.e. one has higher temperature than inlet temperature (hot air) and other one has lower temperature than inlet temperature (cold air) simultaneously from the compressed gas. It can be used for spot cooling applications like drilling, welding etc. The working mechanism of vortex tube can be observed physically, but tough to explain, as there is no perfect explanation to explain the phenomenon. In vortex tube compressed air is sent at an angle (tangentially) through the nozzle. The circular or vortex motion of compressed air inside the vortex tube is produced by swirl generators. As the vortex drives inside the tube, 2 temperature streams are formed. The high temperature stream moves along the tube circumference while low temperature stream is in the inner core axis. The higher temperature stream is then allowed to release through the control valve located at one end of the tube and the lower temperature stream is then reflected back from the control valve and released through another end of the tube. This results temperature distribution inside the vortex tube.

II. VORTEX TUBE:

The Vortex tube which is a mechanical device working as one of the non-conventional refrigerating or cooling machine without any movable part, by dividing a compressed air into a low temperature region than inlet temperature region and a high temperature region than inlet temperature region. Division of 2 different temperatures is known as temperature separation effect. The air coming from the hot end can be around 190 °C, and the air coming from the "cold end" can be around -50 °C. When compressed gas is passed at an angle (tangentially) into the vortex tube chamber through the nozzle, a circular flow is produced inside this chamber. When the air circulates inside the centre of this chamber, it is aggrandized and cooled. In this chamber, part of the air circulates to the hot end, and another part coming out through the cold side. Component of the air in the vortex tube reverses from the control valve and move from the higher temperature end to the lower temperature end. And hence at the control valve side the air released with a higher temperature as compared to inlet temperature, while at another end, the low temperature air is released.

International Journal of Research

Available at https://edupediapublications.org/journals

p-ISSN: 2348-6848
e-ISSN: 2348-795X
Volume 03 Issue 08
April 2016

III. WORKING:

When compressed air is passed from compressor through the nozzle we have made holes at an angle (tangentially) and then it passes through that hole with high velocity and hence, air moves towards the control valve through the hot side pipe. Then 2 types of vortex flow is created in this chamber i.e. free and forced one and air travels in circular like motion along the circumference of hot side. As the air travels in the hot side pipe towards the control valve by using the opening of this valve the flow can be restricted. When the pressure inside the hot side tube near to the valve is greater than outside atmospheric pressure by using the valve, then reversed flow starts through the central portion of hot side pipe from high pressure region to low pressure region. In this process, energy interaction takes place between these 2 streams (i.e. reversed and forward) and therefore air stream through the central portion has lower temperature than the inlet whereas the air stream in forward direction has higher temperature than inlet temperature. Then, the air stream which gets back towards the diaphragm and when it passes through the hole present in this diaphragm hole the air gets cooled and comes out from the cold side pipe, while another air stream is passed through the opening of the valve. With the change in control valve openings, we can get various values of temperature difference at cold end and hot end.

IV. PHENOMENON OF ENERGY TRANSFER:

As we know many researchers has a proposed theory for the energy exchange phenomenon between the hot stream and cold air stream in vortex tube. But no theory has been able to explain this unconventional energy interaction.

Van Deemter gave an explanation that when compressed air passes into the tube it creates 2 type of vortex flow i.e. free and forced vortex motion. Centrifugal

acceleration helps the vortex to move along the circumference. Now as this vortex move towards the end where we have placed the control valve, rotation of the air almost stops. So there is the generation of stagnation conditions in the tube. Due to this pressure inside the tube starts to rise and when it becomes greater than the outside pressure i.e. atmospheric pressure, a flow in reversed direction is generated. This flow moves to the opposite direction of original flow from vortex chamber. This reversed flow is also known as forced vortex flow.

The velocity of the free vortex decreases as it moves from nozzle to valve at end, which causes the sliding between 2 adjacent planes, which are moving towards the valve.

An another hypothesis was given by Prof. Parulekar which states that turbulent mixing in centrifugal fluids cause the energy transfer from low pressure to high pressure.

When compressed air is passed to the vortex chamber it will produce a free vortex motion of air. Now this air will flow toward the end of tube where we have a control valve in the shape of conical. As per theory given by Van Deemeter, stagnation condition is created at the end. Now when pressure near the valve rises with more than outside atmospheric pressure, a reversed flow is generated. The free vortex which moves in forward direction will influence this reversed flow. Then, it will create a reversed flow which is known as forced vortex flow. Energy is needed to create this forced vortex which is provided by free vortex. This amount of energy transferred by free vortex is less than the amount of energy transferred from inner core to the circumference. Hence, we will get the air with less temperature than inlet temperature at one end and the air with more temperature than inlet temperature at another end where we have placed control valve.

International Journal of Research

Available at https://edupediapublications.org/journals

p-ISSN: 2348-6848
e-ISSN: 2348-795X
Volume 03 Issue 08
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These are the 2 hypothesis by which we can understand how energy interacts and how we will get the cold air and hot air in 2 different ends.

V. PARTS OF VORTEX TUBE:

I. **NOZZLE:** It is a mechanical device that is used to increase the velocity of any stream by decreasing its area at the end and it is placed at the end of any pipe or hose.

II. **DIAPHRAGM:** It is a circular in cross-section with very small thickness having a small hole of specific diameter at the centre. Air stream travelling through the core of hot side is emitted to the diaphragm hole and hence it gets expanded and gets cooled.

III. **VALVE:** Valve is used to obstruct the flow of air at the hot side so that by controlling it we can get cold air on the other end of tube and it is also used to check the quantity of hot air through vortex tube.

IV. **HOT AIR SIDE:** In the Vortex tube, this is cylindrical in cross section and it can be varied by taking different lengths as per experiment.

V. **COLD AIR SIDE:** In the Vortex tube, this is also in cylindrical cross-section through which cold air is passed and its length is depending on the length of hot side.

VI. FABRICATION AND ANALYSIS:

1) **Chlorinated polyvinyl chloride (CPVC):** It is a thermoplastic which can be made by chlorination of polyvinyl chloride i.e. pvc resin. It can be used for common replacement for metal piping because its strength, easy installation and low cost. CPVC which is a thermoplastic material i.e. it can be moulded into different shapes to create pipes, valves and other liquid handling supplies. CPVC can withstand a wider range of temperatures. Temperature over 60 degree Celsius can softening of material and weakening of joints but CPVC can handle temperature up to 94 degree Celsius. The more resisting properties of CPVC make it useful for various applications. CPVC exhibits fire-retardant properties.

2) **CONSTRUCTIONS DETAILS:** We have designed 2 different vortex tube by taking different length for hot and cold side and different diameter of pipes so that we will get 2 length and diameter ratio i.e. L/D.

	PIPE A	PIPE B
LENGTH OF HOT SIDE (MM)	400	450
LENGTH OF COLD SIDE(MM)	100	150
DIAMETER OF HOT SIDE(MM)	25.4	19.05
DIAMETER OF COLD SIDE(MM)	25.4	19.05
L/D RATIO(MM)	19.68	31.49
DIAMETER OF ORIFICE(MM)	12.7	9.525

3) **EXPERIMENTAL PROCEDURE:** At first we run the compressor for 15mins to get stable pressure. Throughout our experiment we have maintained the input conditions constant. As we pass the pressurized air into the vortex chamber through the holes that are made at an angle i.e. tangentially then, in this chamber first air circulates and enter through the holes that are made in the hot side pipe and air moves towards the hot end where we have setup of control valve. As the air reaches near the control valve and when the pressure of the air becomes greater than the outside atmospheric pressure by partially closing the control valve, a reversal axial flow takes place through the core of hot side which starts from high pressure region to low pressure region and hence, heat interaction takes place between reversed stream and forward

stream. Therefore, air stream passing through the core gets lower temperature than the inlet temperature while air stream which is moving towards the control valve gets higher temperature than inlet temperature. With the change in control valve openings, we can get various values of temperature difference at cold end and hot end.

4)   **ANALYSIS:** For given L/D ratio of pipe A and pipe B, here are the temperature and pressure variation given as follows:

For pipe A : L/D is 19.68 mm

| S.No	PRESSURE(BAR)	TEMPERATURE AT COLD END(DEG. CELSIUS)	TEMPERATURE AT HOT END(DEG. CELSIUS)
1	4.0	24.8	38.1
2	4.5	23.2	39.8
3	5.0	22.1	40.1
4	5.5	21.4	41.9

TABLE NO 1(Pressure and Temperature)

S.No	PRESSURE(BAR)	$\Delta T_C = T_i - T_c$(DEG. CELSIUS)	$\Delta T_H = T_h - T_i$(DEG. CELSIUS)
1	4.0	7.2	6.1
2	4.5	8.8	7.8
3	5.0	9.9	8.1
4	5.5	10.6	9.8

TABLE NO 2(Pressure and Temperature Difference)

For pipe B: L/D is 31.49mm

S.No	PRESSURE(BAR)	TEMPERATURE AT COLD END(DEG. CELSIUS)	TEMPERATURE AT HOT END(DEG. CELSIUS)
1	4.0	21.7	41.5
2	4.5	20.3	43.2
3	5.0	19.1	45.8
4	5.5	18.5	47.1

TABLE NO 3(Pressure and Temperature)

| S.No	PRESSURE(BAR)	$\Delta T_C = T_i - T_c$(DEG. CELSIUS)	$\Delta T_H = T_h - T_i$(DEG CELSIUS)
1	4.0	10.3	9.5
2	4.5	11.7	11.2
3	5.0	12.9	13.8
4	5.5	13.5	15.1

TABLE NO 4(Pressure and Temperature Difference)

VII.   RESULT AND CONCLUSION:

We have taken 2 pipes i.e. pipe A and pipe B and their L/D ratios are 19.68 and 31.49 respectively. As from the graph no 1 and 2 we can see that the cooling effect depends upon L/D ratio. As we increases L/D ratio the pipe delivers more cooling effect and we also notice that as we increases the pressure the cooling effect increases.
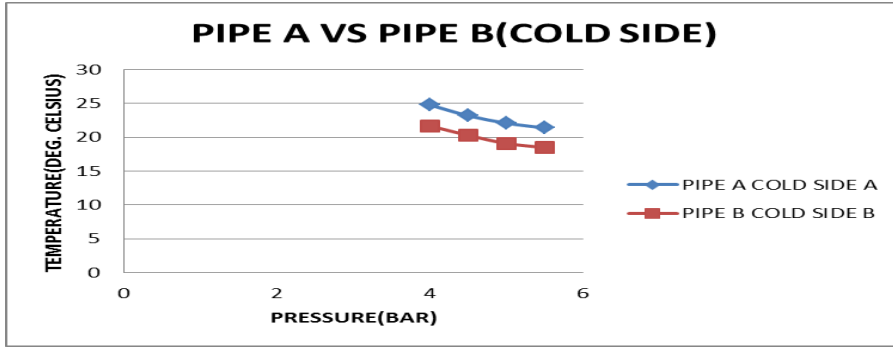
Graph no 1(Pipe A vs Pipe B)
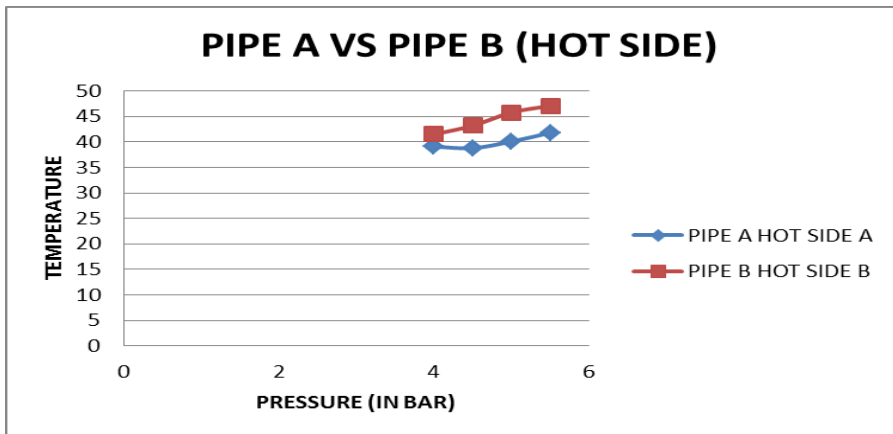
Graph no 2(Pipe A vs Pipe B)

In graph no 3 and 4 we have seen the change in temperature from initial stage at both the end for an individual pipe separately by varying the pressure.
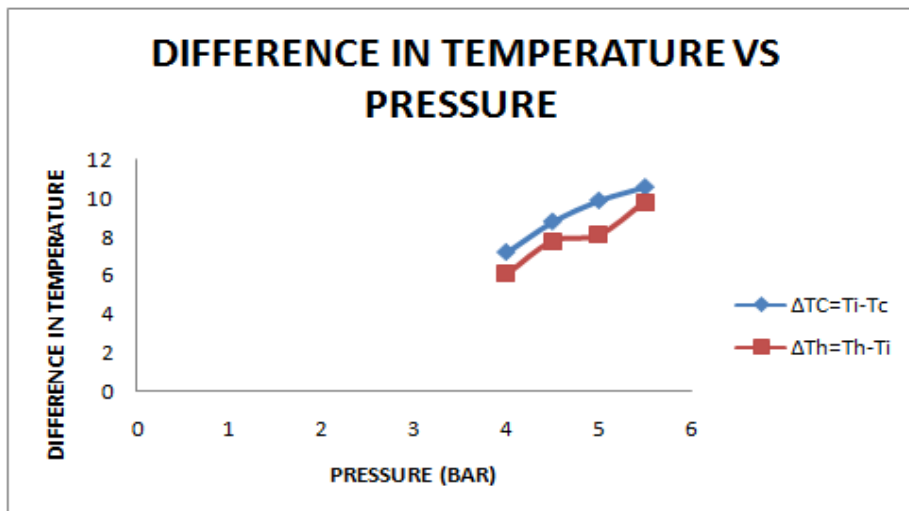
$\Delta T_C = T_I - T_C$
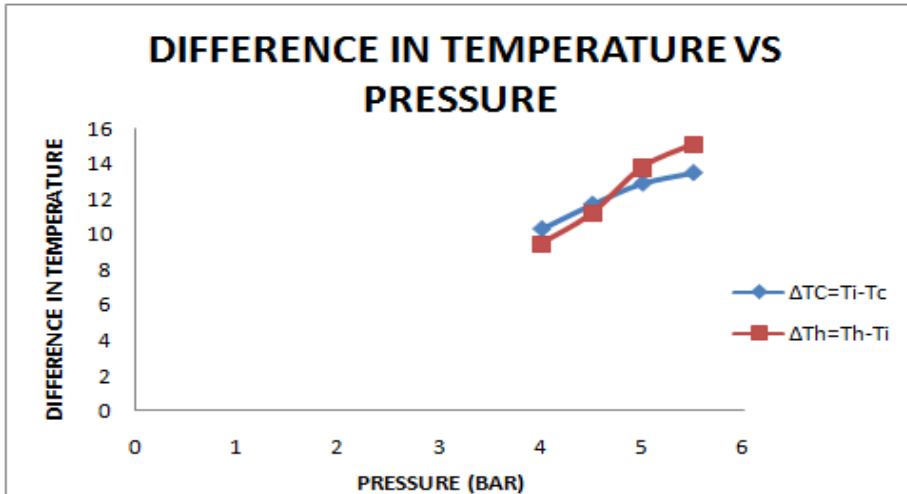$\Delta T_H = T_H - T_I$
Where,
T_I = Inlet temperature
T_C = Cold end temperature
T_H = Hot end temperature
As we increase the pressure the ΔT_C and ΔT_H gets increase.

Graph no 3

Graph no 4

VIII. CONCLUSION:

From the above analysis we can conclude that as we increases the L/D ratio, we can get more temperature difference between cold end and hot end side. The maximum temperature difference in pipe A between cold end and hot end with initial temperature of the air is 10.6 and 9.8 respectively. The maximum temperature difference in pipe B between cold end and hot end with initial temperature of the air is 13.5 and 15.1 respectively.

IX. REFRENCES:

[1] J. Prabakaran and S.Vaidyanathan(2010) effect of orifice and pressure of counter flow vortex tube Indian J. Sci. technology. http://www.indjst.org

[2] Gao (2005) Experimental study on a simple RanqueHilsch vortex tube. Cryogenics. 45, 173-183.

[3] K. Stephan, S. Lin, M. Durst, F. Huang, and D. Seher, 1983, "An Investigation of Energy Separation in a Vortex Tube", International Journal of Heat and Mass Transfer, Vol. 26, No. 3, pp. 341-348.

[4] Ranque gj " experiments in expansion in a vortex tube with simultaneous exhaust of hot air and cold air".

[5] Refrigeration and air-conditioning by Domkundwar.

[6] Experimental investigation the effects of orifice diameter and tube length on a vortex tube performance by MahyarKargaran and Mahmood Farzaneh.

[7] The effect of l/d ratio on the temperature separation in the counter flow vortex tube Nader Pourmahmoud &Abdol Reza Bramo.

[8] A review on design criteria for vortex tubes by M. Yilmaz, M. Kaya, S. Karagoz, S. Erdogan.

[9] Prof. P.S. Desai, "Refrigeration & Air Conditioning" Khanna publishers; 2004.

[10] S.S. Thipse, "Refrigeration & Air Conditioning" Jaico publishing house; 2007.

[11] Q. Chang, Q. Li, G. Zhou, Q. Li, Experimental Investigation of Vortex Tube Refrigerator with a Divergent Hot Tube, International Journal of refrigeration, 34 (1), (2011), 322-327.

[12] Newton, James, 2012, "Hilsch Vortex Tube Cooling/Heating", from http://massmind.org/techref/hilschvortex.htm.

[13] H. Takahama, 1965, "Studies on Vortex Tubes", Bulletin of JSME, Vol. 8, No. 3, pp. 433-440.