

Performance Improvement of Ranque-Hilsch Vortex Tube by Using Conical Hot Tube

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Abstract— Refrigeration plays an important role in developing countries, primarily for the preservation of food, medicine, and for air conditioning. Conventional refrigeration systems are using Freon as refrigerant. As they are the main cause for depleting ozone layer, extensive research work is going on alternate refrigeration systems. Vortex tube is a non-conventional cooling device, having no moving parts which will produce cold air and hot air from the source of compressed air without affecting the environment. When a high pressure air is tangentially injected into vortex chamber a strong vortex flow will be created which will be split into two air streams. It can be used for any type of spot cooling or heating application. In this paper, vortex tube with cylindrical and conical hot tubes performance is compared. It was found that the vortex tube with a conical angle of about 2.5° surpassed the cylinder tube by 25%~30% in COP. The conical vortex tube reaches the same or more performance than the normal tube but with a smaller length.

Keywords: Ranque-Hilsch vortex tube, Temperature separation, Flow visualization, Geometrical parameters

I. Introduction

Vortex tube (VT) is a device that generates cold and hot air stream from the source of compressed air. It contains the parts: inlet nozzle, vortex chamber, cold-end orifice, hot-end control valve and tube. Fig.1 shows the construction of vortex tube. When high pressure gas is tangentially injected into the vortex chamber through the inlet nozzles, a swirling flow is created inside the vortex chamber. In the vortex chamber, part of the gas swirls to the hot end and another part exist through the cold end directly. Part of the gas in the vortex tube reverses for axial component of the velocity and move from the hot end to the cold end. At the hot end, the air escapes with higher temperature, while at the cold end, the air has lower temperature compared to that of the inlet temperature pass through the orifice. This was discovered by Ranque (1933) and later developed by Hilsch (1947). In memory of

their contribution the Vortex tube is also known as Ranque-Hilsch vortex tube (RHVT). Analytical study on vortex tube was discussed by Lay (1959). Soni and Thomson (1975) gave the expressions for designing vortex tube. Hartnet and Eckert (1957) investigated with large size vortex tube. Gao (2005) investigated that the entry to the hot end is important for the energy separation. Behera et al., (2005) carried out simulation of vortex tube using CFD. Arjomandi and Yenpeng (2007) used new hot end plug which improved the performance of vortex tube. kirmaci (2009) used statistical method to optimize the vortex tube.

RHVT has the following advantages compared to the normal commercial refrigeration device. Simple in constructions, no moving parts, no chemicals, light weight, low cost, maintenance free, instant cold air, durable for its application. Therefore, if compactness, reliability and lower equipment cost are the main factors, then the vortex tube are recommended for spot cooling. Now lot of research works is going on the vortex tube to improve its performance.

II. Working principle

Compressed air at high pressure enters the vortex tube through tangential nozzle where the flow gets accelerated. Due to tangential entry, the air has high velocity and rotates at very high speed. Thus the air has whirling or vortex motion in vortex chamber, which subsequently spiral down the tube to right side (depends on the direction of spiral). The central core of the air is reversed by means of a conical valve, which control the pressure in the system. The end of the cold pipe, which built up with the vortex chamber, is fitted with a washer that has the half the diameter of the pipe. Washers with different diameter are also used to adjust the system. The reversed air at low temperature moving through the washer to the cold section. Thus cold air is produced at the left side of vortex chamber. Hot air is produced at the right side through the conical valve.

Design and construction details

The design details of vortex tube: Diameter of vortex tube $D=20$ mm; Length of vortex tube $L=135$ mm. Diameter of

orifice $D_o = 6$ mm, Diameter of nozzle $D_N = 5$ mm, No of nozzle= 1, Material= Mild steel, Inlet pressure= 2 bar -6 bar, conical angle 2.5° .

III. Experimental part

The experimental setup consists of compressor, vortex tube and temperature indicator. A stop valve at the compressor reservoir exit controls the inlet air to the vortex chamber. The inlet pressure is measured using pressure gauge. The temperatures of the air at inlet, at cold end, at hot end and ambient air are measured using thermocouple (copper constantan). Fig. 2 shows the overall view of the experimental setup. The compressor was initially run for about 20 min. to get a stable compressor air tank pressure of 2 bar (g). Temperatures at all location are tabulated. Then the same sets of readings are taken at a pressure of 3, 4, 5 and 6 bar. The temperatures of the air at cold and hot end are the vital parameters that determine the COP of the vortex tube. The experiment is conducted with both cylindrical and conical hot tube.

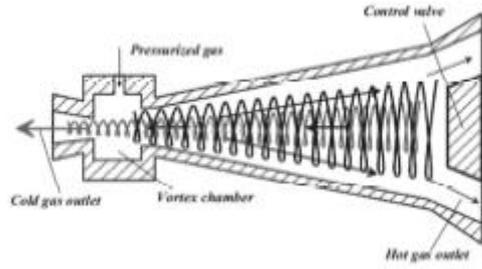


Fig. 4. Inlet pressure Vs Cold End Temperature

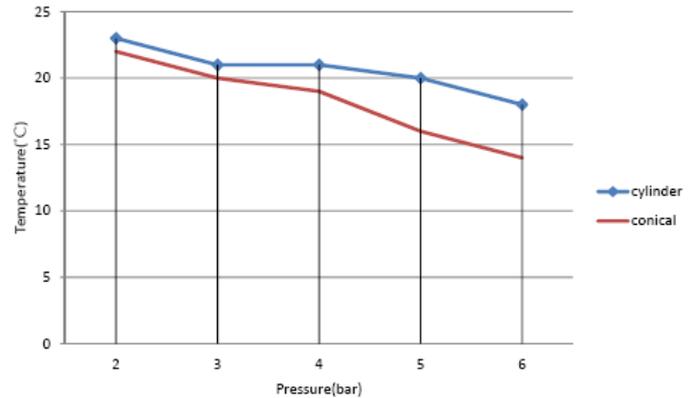


Fig. 1. Construction of vortex tube

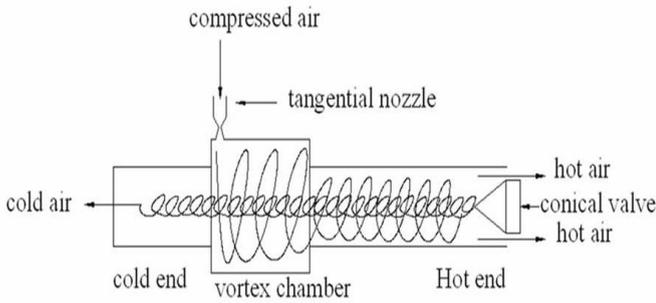


Fig. 2. Experimental setup

Fig. 5. Inlet pressure Vs Hot End Temperature

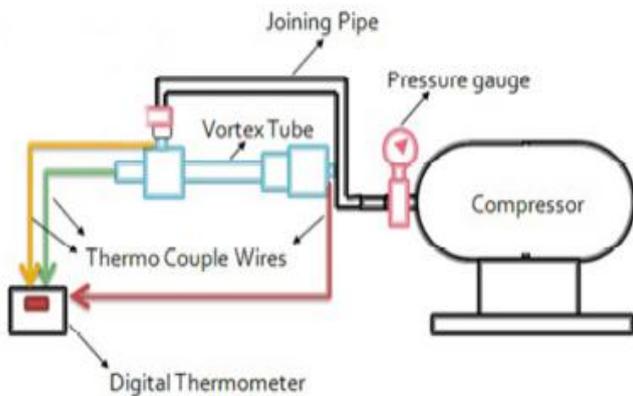
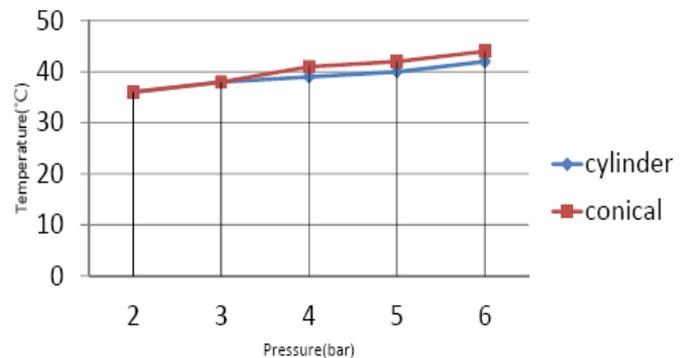
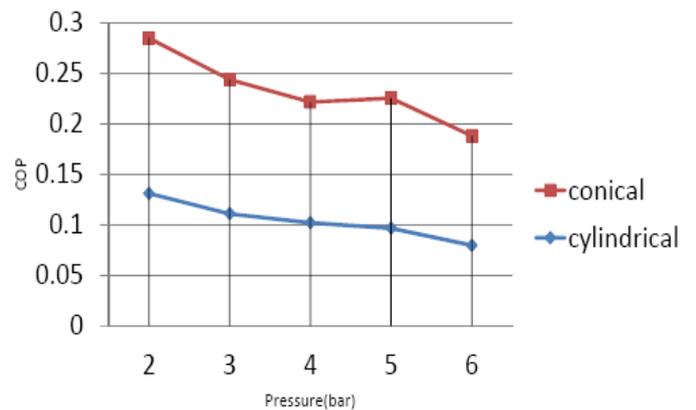


Fig. 3. Conical Vortex tube.

Fig. 6. Inlet pressure Vs COP



IV. Results and discussion

From the Fig. 4 it is clear that at any given pressure the temperature of the conical hot tube is better when compared to cylindrical hot tube and the temperature difference between them is proportional to pressure i.e., the temperature difference is increasing progressively with pressure. From the Fig. 5 the temperature of hot end for conical hot tube is more compared to cylindrical hot tube .from this we can say that temperature difference between them is proportional to pressure i.e., the temperature difference is increasing progressively with pressure. Fig. 6 is plotted for pressure V/ COP. From the graph it is noted that the COP of the vortex tube with conical hot end is higher than the vortex tube with cylindrical hot tube. From the Fig. 4, Fig. 5, Fig. 6 it is noted that the performance of the vortex tube with conical hot tube is better than the vortex tube with cylindrical hot tube. After evaluating the performance of vortex tube with cylindrical and conical hot tubes it was found that the vortex tube with conical hot tube gives the better performance than the cylindrical hot tube i.e. there is an increase in COP of about 25%-30%. The Cold temperature, hot temperature and COP values obtained for cylindrical and conical hot tubes at various pressures are:

TABLE.1. Vortex Tube with Cylindrical Hot Tube

S:NO	Pressure Pi(bar)	Cold temperature Tc(°C)	Hot temperature Th(°C)	COP
1	2	23	36	0.0798
2	3	21	38	0.0967
3	4	21	39	0.1022
4	5	20	40	0.1111
5	6	18	42	0.1311

TABLE.2. Vortex Tube with Conical Hot Tube

S:NO	Pressure Pi(bar)	Cold temperature Tc(°C)	Hot temperature Th(°C)	COP
1	2	22	36	0.1085
2	3	20	38	0.1289
3	4	19	41	0.1196
4	5	16	42	0.1330
5	6	14	44	0.1540

TABLE.3. COP of Vortex Tube with Cylindrical Hot Tube and Conical Hot Tube

S.No	Pressure in bar	COP of cylinder hot tube	COP of conical hot tube	% increase in COP of conical hot tube
1	2	0.0798	0.1085	35.96
2	3	0.0967	0.1289	33.29
3	4	0.1022	0.1196	17.25
4	5	0.1111	0.1330	19.71
5	6	0.1311	0.1540	17.46

The performance of the vortex tube was evaluated by conducting the experiment by replacing the cylindrical hot tube with a conical hot tube at various inlet pressures. The other parameters like orifice diameter, nozzle is kept unchanged. The highest COP is obtained at 6 bar for taper tube and the value is 0.1540. The lowest cold temperature for vortex tube with conical hot tube is 14°C at 6 bar and with cylindrical hot tube is 18°C at 6 bar. The highest hot temperature for vortex tube with conical hot tube is 44°C at 6 bar and with cylindrical hot tube is 42°C at 6 bar. Cold mass fraction obtained is better for the vortex tube with the conical hot tube than the cylindrical hot tube. The maximum of 30°C difference between hot and cold ends temperature for vortex tube with the conical hot tube and maximum of 24°C difference between hot and cold ends temperature for vortex tube with the cylindrical tube is obtained.

V. Conclusion

The effect of the conical hot tube on the cold temperature drop, hot temperature raise, and COP of the Vortex tube are analyzed. The Cold drop temperature ΔT_c increases with increase in inlet air pressure. The Hot temperature raise ΔT_h increases with increase in inlet air pressure. The COP of the vortex tube increases with increase in inlet pressure.

From the results obtained, it was found that the performance of the vortex tube is better for conical hot tube. The optimum end gate value opening gives the best performance. The effect of nozzle design is more important than the cold orifice design in getting higher temperature drops. The surface finish of the nozzle and the hot tube plays a great role in the performance of the vortex tube , good surface finish leads to the better performance .so ,care to be taken while fabrication of the parts to obtain to get good surface finish. From the above results, it is suggested to have the conical angle of 2° to 3°.

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