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Performance Analysis of Vortex Tube Refrigerator

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***Abstract*— Refrigeration is a process of removing heat from a substance under controlled conditions. Today's refrigeration systems are not only used for making ice and other similar products but also used for preservation of food, medicines etc. Vortex tube, a highly sophisticated system is a non-conventional method of producing cooling effect. It is a simple device for producing cold air and hot air simultaneously using compressed air as refrigerant; hence vortex cooling is an environmentally friendly system. It does not have any moving parts. In the present work vortex tube is fabricated and analysed for its performance.**

***Keywords*— Refrigeration, Vortex tube, non --conventional method, compressed air, environmentally friendly.**

I. INTRODUCTION

The vortex tube, also known as the Ranque-Hilsch vortex tube (RHVT) is a device which generates separated flows of cold and hot gases from a Single compressed gas source. The vortex tube was invented quite by accident in 1931 by George Ranque, a French physics student, while experimenting with a vortex-type pump that he had developed, and then he noticed warm air exhausting from one end, and cold air from the other. Ranque soon forgot about his pump and started a small firm to exploit the commercial potential for this strange device that produced hot and cold air with no moving parts. However, it soon failed and the vortex tube slipped into obscurity until 1945.

A. Components Of Vortex Tube

Nozzle: The nozzle are of converging type, diverging type or converging-diverging type as per the the design. An efficient nozzle is designed to have higher velocity, greater mass flow and minimum inlet losses.

Diaphragm: It is a cylindrical piece of small thickness and having a small hole of specific diameter at the centre. Air stream travelling through the core of the hot side is emitted through the diaphragm hole.

Valve: It obstructs the flow of air through hot side and it controls the quantity of hot air through the vortex tube.

Hot side: It is cylindrical in cross section and has a suitable length based on the design. The effective length of hot side is taken as 3D for efficient operation of he vortex tube.

Cold side: It is a cylindrical portion through which cold air is been passed.

Chamber: It is a portion of the nozzle in the same plane of the nozzle and facilitates the tangential entry of high velocity air stream into hot side.

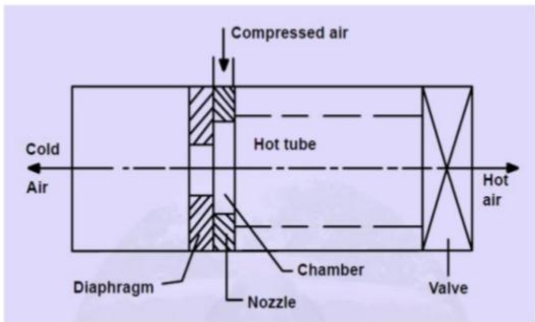

Fig 1: Schematic showing major components of vortex tube

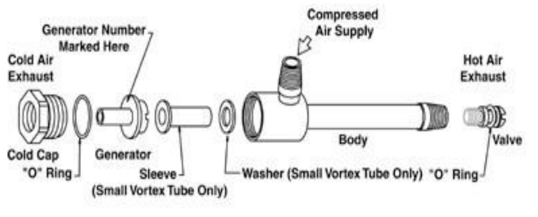

Fig 2: Disassembled components of vortex tube

Fig 3: Fabricaed components of vortex tube

B. Working:

Compressed air is passed through the nozzle. Then the air expands and acquires high velocity due to particular shape of nozzle.

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A vortex flow is created in chamber and air travels as spiral like motion along the periphery of hot side. When the pressure of the air near the valve is made more than the outside by partially closing the valve, a reverse axial flow through the core of the hot side starts from high pressure to low pressure region. During this process energy transfer takes place between reversed stream and forward stream. The air stream passes through the core get cooled below the inlet temperature of the air in the vortex tube and while the air stream in the forward direction gets heated. The cold stream is escaped through the diaphragm hole into the cold side and while hot stream is passed through the opening of the valve. By controlling the opening valve, the quantity of cold air and its temperature can be varied.

II. Modelling And Fabrication Of Vorex Tube

Vortex tube is modelled using the desired dimensions in CATIA and then fabricated.

DETAIL	DIMENSIONS
HOT OUTLET DIAMETER	12mm
LENGTH OF CHAMBER	36mm
COLD OUTLET DIAMETER	26mm
CHAMBER DIAMETER	30mm
LENGTH OF THE TUBE	150mm

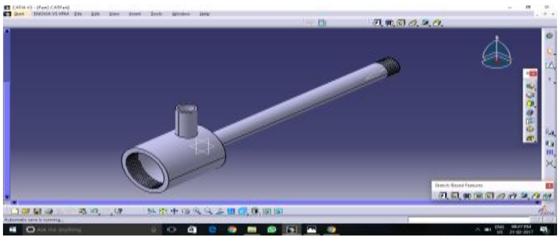

Fig 4: Main body of vortex tube

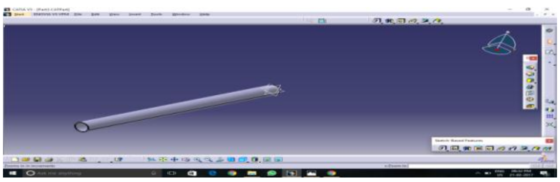

Fig 5: Sleeve

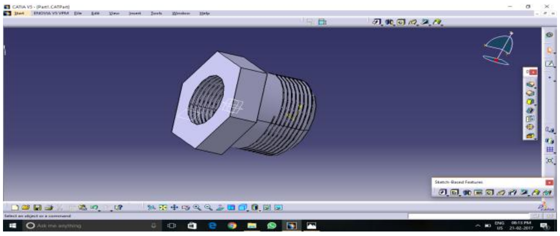

Fig 6: Cold Cap

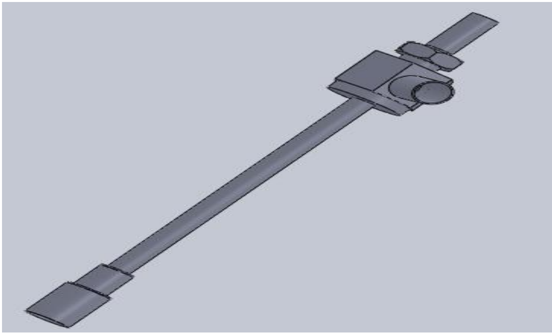

Fig 7: Isometric view of vortex tube

Fig 8: Fabricated Vortex tube

III. Experimentation

The experimental setup consists of air compressor and a vortex tube. 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 temperature of the air at inlet, cold end, hot end and ambient is measured using thermocouples.

IV. Results And Discussions

From the experiments conducted on vortex tube the following results are obtained as tabulated below.

TABLE I
Readings and calculated values

S.No	Pressure P_i, Bar	Cold Temp (T_c), °C	Hot Temp (T_h), °C	Difference $\Delta T = T_h - T_c$, °C	Inlet Temp (T_i), °C	Cold Temp Drop ΔT_c, °C	Hot Temp Drop ΔT_h, °C	Cold mass Fraction µ	Adiabatic Efficiency, n_{ab}	COP
1.	2	-1	26	27	16	17	10	0.41	0.60	0.079
2.	5	-6	35	41	20	26	15	0.46	0.56	0.096
3.	7	-9	39	48	23	32	16	0.48	0.51	0.102
4.	10	-13	42	55	25	38	17	0.50	0.50	0.110
5.	12	-16	46	62	27	43	19	0.51	0.48	0.113

The required parameters are estimated using the following equations

Cold mass fraction $\mu = \frac{m_c}{m_i}$

Adiabatic efficiency of compressor

$$n_{ac} = \frac{m_i T_i c_p [\left(\frac{p_i}{p_a}\right)^{\frac{\gamma-1}{\gamma}} - 1]}{m_c c_p \Delta T_c}$$

Adiabatic efficiency of vortex tube

$$n_{ab} = \mu \Delta T_{rel} = \mu \frac{\Delta T_c}{\Delta T_c'}$$

Coefficient of performance of vortex tube

$$\text{COP} = n_{ab} n_{ac} \left(\frac{p_a}{p_i}\right)^{\frac{\gamma-1}{\gamma}}$$

From the results obtained it is clear that

i. The temperature difference ΔT increases rapidly from 27°C to 62°C as inlet pressure increases from 2 bar to 12 bar.

ii. The value of ΔT_c increases significantly from 17°C to 43°C with increase in inlet pressure P_i from 2 bar to 12 bar and the trend is linear up to certain pressure and then deviates from the linear relationship. This is due o the physical property of air.

iii. The value of ΔT_c increases from 17°C to 43°C increases with cold mass fraction µ from 0.41 to 0.51.

iv. The adiabatic efficiency of vortex tube decreases gradually from 0.6 to 0.48 as ΔT_c increases from 17°C to 43°C.

V. CONCLUSIONS

i. COP of vortex tube is very low of order 0.1. In spite of its less COP it is still used in industries where dry compressed air is available and is used for spot cooling of electronic components. It is commonly used in USSR for cooling of bodies of persons working in mines.

ii. With efficient design it is possible to attain temperatures as low as -50°C without any difficulty.

REFERENCES

[1] FikretKocabas, Modeling of heating and cooling performance of counter flow type vortex tube by sing artificial neural network, Elsevier Journal, February 2010.

[2] K. Dincer, Experimental investigation and exergy analysis of the performance of a counter flow Ranque-Hilsch vortex tube with regard to nozzle cross-section areas, Elsevier Journal, April 2010.

[3] Prabakaran.J, Effect of Diameter of Orifice and Nozzle on the performance of Counter flow Vortex tube, IJEST Journal, 2010.

[4] J. Prabakaran, Effect of orifice and pressure of counter flow vortex tube, IJST, April 2010.

[5] Nader Pourmahmoud, The effect of L/D ratio on the Temperature separation in the Counter flow vortex tube, IJRRAS Journal, January 2011.

[6] Tejshree Bornare, Vortex tube refrigeration system based on compressed air, IAEME, Vol. 6, Issue 7, June 2015.

[7] S. Kalim Vali, An efficient vortex tube with Maximum C.O.P., IJERT, Vol. 3, Issue1, Jan-2014.

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[8] Waraporn Rattanongphisat, Improvement vortex cooling capacity by reducing hot tube surface temperature: Experiment, Energy Procedia 52 (2014) 1-9.

[9] S.C Arora and S. Domkundwar, A course in refrigeration and air conditioning, DhanapatRai & Sons Publications.

[10] Soni and Thomson, Optimal design of Ranque Hilsch vortex tube. *ASME* J. Heat transfer. **94**(2), 1975, pp.316- 317.

[11] Volkan Kirmaci, Energy analysis and performance of a counter flow Ranque Hilsch vortex tube having various nozzle numbers at different inlet Pressures of oxygen and air, *Elsevier journal*, May 2009.