International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 4 Issue 03, March-2015

An Experimental Setup of Vortex Tube Refrigeration System

Karthik S
Department of Mechanical Engineering
Mohandas college of Engg.& Tech
University of Kerala
Kerala, India

***Abstract*— The vortex tube is a refrigerating equipment that produces both cold as well as hot air at both opposite ends. The vortex tube's construction is such that it is made up of a hollow tube of either metallic or fibre components having a nozzle for letting in of compressed air and a diaphragm or a orifice for controlling the flow rate of air. When compressed air passes through a nozzle into the diaphragm of the vortex tube, the air forms a spiral shaped vortex, that causes the heating up of air, and when this air returns back, it cools down rapidly, producing a cooling effect. The main study in the Vortex tube is the study of the temperature distribution of the rotating air. This effect was first discovered by Ranque and later by Hilsch and hence this effect is called Ranque-Hilsch effect.**

Keywords- Vortex Tube, Cooling;

I. INTRODUCTION

The effect of vortex tube was first discovered by George Ranque in the year 1933. This effect was observed by Ranque while observing thermal division in a cyclone separator. In the year 1947, the design was improved by Hilsch. After that, a lot of scientists performed theoretical as well as a practical studies on the Vortex effect; for example Kassner and Knoemschild performed a study based on the assumption that the effect was due to a adiabatic expansion, which lead to a low temperature in the low pressure area near the axis of the tube. Even after various tests and analysis,
no theory provides a proper explanation for the vortex mechanism undergoing in the tube.

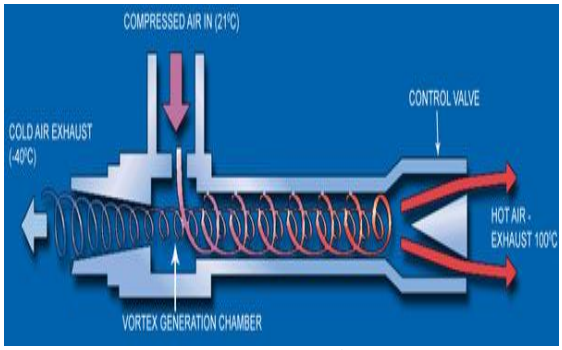


Fig. 1. Schematic diagram of a Vortex tube

The schematic of vortex tube consists of a cylindrical tube with a nozzle, a diaphragm (cylindrical plate with a central hole) and a control valve. Compressed air is kept tangential through the nozzle which is kept tangential to the tube.
The Vortex Tube is now being used commercially for various applications such as food preservation and cooling in mines as the apparatus is very simple and compact and it doesn't require any interaction of heat and work with the environment for its operation.

II. LITERATURE REVIEW

After initial experiments, a lot of researchers tried a lot of modifications on the vortex tube to increase it's performance. It is found from the previous scientist's records that each and every one of them used various L/D ratios and each one of them was a result of hit and trial method.

The list is given below regarding the modifications and customisations:-

TableI. Previous reviews

SCIENTIST	L *(inch)*	D *(inch)*	Nozzle dia *(inch)*	year	Cold end orifice dia*(dc)*	dr=dc/ D
TAKAHAMA	317	2	0.5	1980	-	-
REYNOLDS	48	3	0.12	1985	127	0.42
AHLBORN	24	1	-	1997	0.328	0.33
C.RAO	8	0.63	0.12	2005	0.16	0.25
NINMBALKAR	10	0.75	0.162	2011	0.38	0.50

It is clearly evident from the above table that the various ratio parameters used in the construction of the vortex tube for different authors have no relation with each other. Each person has his own combinations of the ratio parameters.

III. DESIGN PROCEDURE

The main aim of this setup is the production of a Vortex path of air. Since the nozzle is tangential, air entering through it gets a swirling motion inside the cylinder. The air acquires a high velocity and travel towards the valve (in the end of the hot side) as a spiral vortex. When the swirling flow reaches the end, it is resisted by the partially opened valve. Due to the conversion of kinetic energy, the pressure of the air near the valve increases and a reversed axial flow through the low pressure case.

By controlling the opening of the valve, the proportion of cold air and hot air and their temperatures can be varied.
some of the restrictions followed were:-

1. For obtaining the maximum temperature difference at cold end, the ratio L/D should be maintained in the range of $30 \leq L/D \leq 60$.
hence, considering the length to be 113.03cm and diameter to be 2.05cm, we get the L/D ratio to be in the range.

2. Decreasing conical valve angle have positive effect on performance of vortex tube but not so much difference is observed in the temperature reduction. Therefore it is better to use conical valve with smaller angle in order to improve the performance of vortex tube.

3. The following schematics is followed-

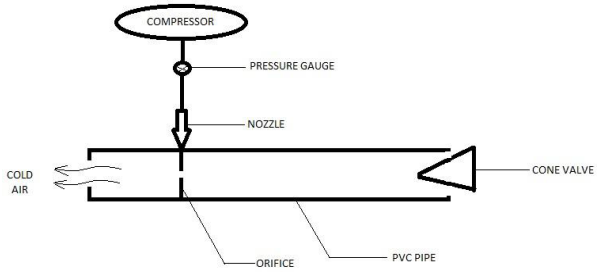


Fig.2 . Schematics

IV. DESIGN PARAMETERS

The primary material used is PVC pipe for the vortex tube refrigerator. the cone valve used is of a wooden material.

In the current investigation, the design parameters used are provided in the table below.

TableII. Design parameters used for vortex tube

Tube inner diameter	0.81"	d
Hot end length	36.5"	45d
Cold end length	8"	10d
Orifice size	0.4"	0.5d
Inlet nozzles	0.12"	6.75d

The total length of the vortex tube made from the PVC pipe was found out to be 113.03cm; having the length of the hot side to be 92.71cm and that of cold side to be 20.32cm.

.

V. ANALYSIS

The analysis done is to compare the experimental and the theoretical value of the vortex tube. Hence, a CFD analysis is carried out to find out the temperature difference as well as the velocity of air passing through the tube.
The performed CFD analysis were-

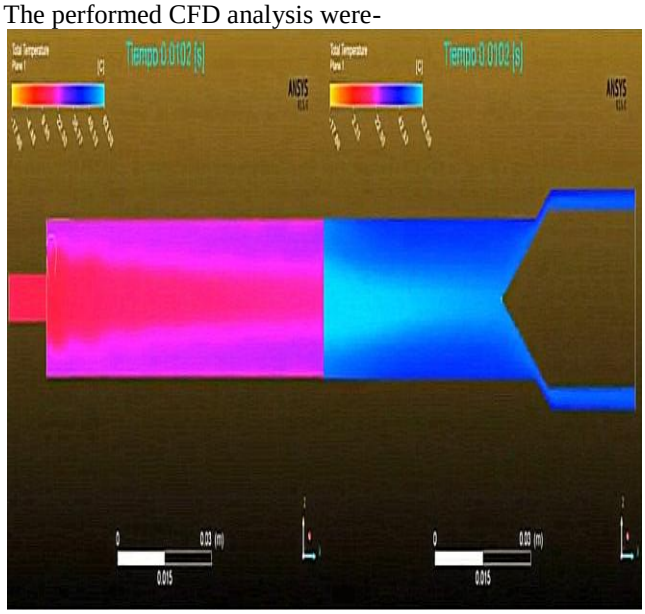


Fig. 3. Thermal Analysis Part 1

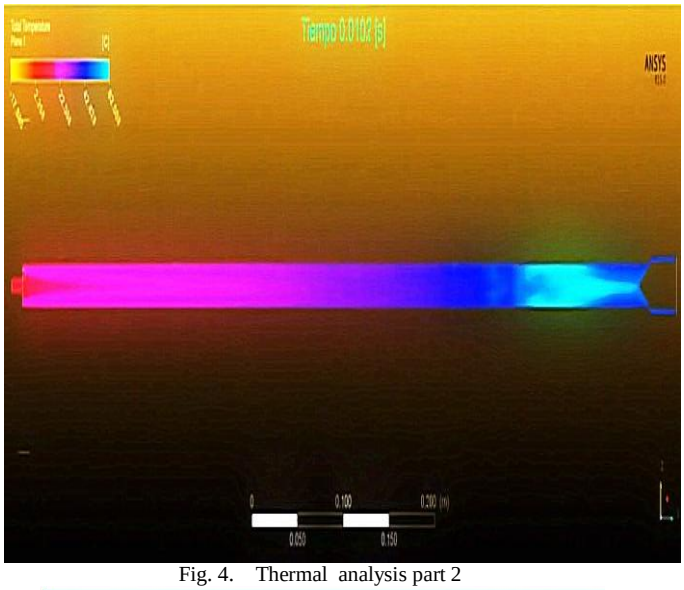


Fig. 4. Thermal analysis part 2

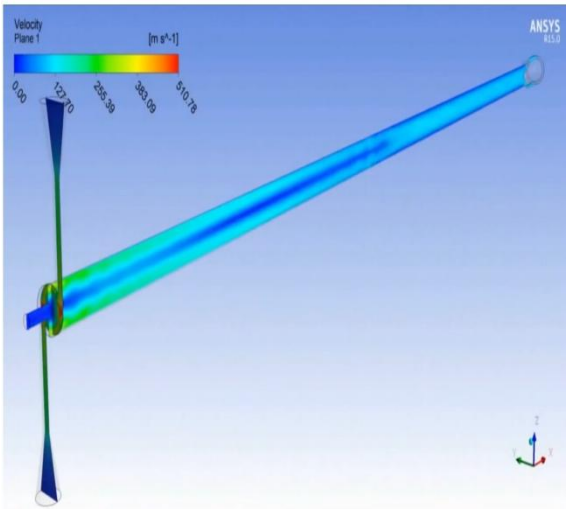
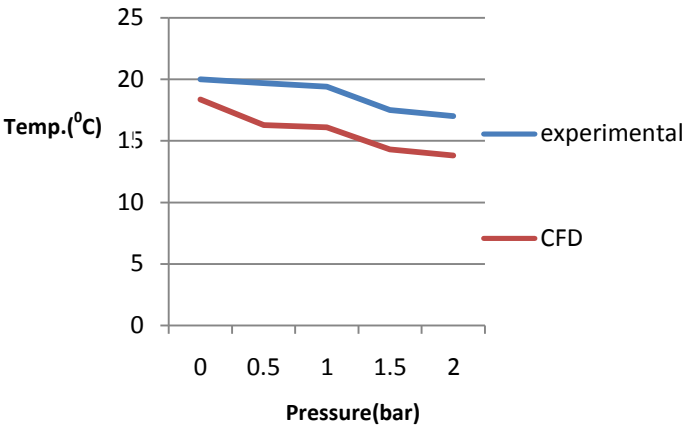


Fig. 5. Velocity analysis

The comparison is as follows :-

Table III. Comparison table

TEMPERATURE ANALYSIS		
PRESSURE *(bar)*	COLD END TEMPERATURE *(^0C)*	
	EXPERIMENTAL	CFD analysis
0	20	18.36
0.5	19.7	16.27
1	19.4	16.1
1.5	17.5	14.3
2	17	13.8



VI. CONCLUSIONS

1. The increase in pressure causes Drop in temperature.
2. The material of the tube has significant importance in the design of the vortex tube. As per comparison, Stainless steel tube is more efficient than the PVC pipe.
3. The hot end plug determines the temperature range obtained in the vortex tube.

ACKNOWLEDGEMENT

I express my sincere gratitude to staffs of Department of Mechanical Engineering of Mohandas College of Engineering and Technology, for providing necessary facilities and encouragement for the assembly and construction of the work on Vortex tube.

REFERENCES

[1] Bramo, A.R, et al: Computational Fluid Dynamics simulation of length to diameter Ratio Effects onThe energy seperation in a vortex tube;Thermal Science, Year 2011, Vol.15, No. 3, pp. 833-848

[2] G J Ranque. 'Experiments on Expansion in a Vortex with Simultaneous Exhaust of Hot and Cold air', The Journal of Physics, Vol 4, June 1933, pp 1125-1130

[3] Sachin U Nimbalkar and Michael R Muller, An experimental investigation of the optimum geometry for the cold end orifice of a vortex tube, Applied thermal Engineering vol.29, 2008 , p 509-51.

[4] R B Aronson. 'The Vortex Tube: Cooling with Compressed air.' Journal of Machine Design, December 1976, pp 140-143

[5] Y Soni and W J Thomson. 'Optimal Design of Ranque-Hilsch Vortex tube'. ASME Journal of Heat transfer, vol94, no 2, May 1975, pp 316-317

[6] V I Metenin. 'Investigations of Vortex Tube Type Compressed air separators'. Soviet Physics- Technical Physics, Vol 5, 1961, pp1025-1032