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An Experimental Investigation Of Vortex Tube

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ABSTRACT

A vortex tube is a device of a simple structure with no moving parts that can be used to separate a compressed gas into a hot stream and a cold stream. Many studies have been carried out to find the mechanisms of the energy separation in the vortex tube. Recent rapid development in computational fluid dynamics is providing a powerful tool to investigate the complex flow in the vortex tube. Experiments have been performed on vortex tube thoroughly and thereafter CFD analysis has been performed. Results offer good insight in to the physics of the problem.

First detailed experimental treatment has been provided at different valve opening and closing positions and steady and unsteadiness in the system has been critically analysed. To add to this pressure study has been performed and critical pressures have been noted down. Based upon this then simulations have been performed to get the better of the physics of complex heat exchange and situation like multiphase flow. Interactive study has been performed and critical developments are noted down before letting conclusions. This will pioneer new benchmarks in the area of vortex tube design.

Index Terms– Vortex tube, Distillation, Clod mass fraction, nylon spinner.

I. INTRODUCTION

One of the applications of thermodynamics is refrigeration where heat is transferred from low temperature region to high temperature region through the working fluid known as refrigerant. Vapour compression and vapour absorption refrigeration systems are two commonly employed conventional systems in almost all the major applications of refrigeration and air-conditioning. However, environmental problems such as ozone depletion and global warming caused due to CFC refrigerants have compelled us to look for other non-conventional systems. Vortex tube is one of the non-conventional systems where natural substance such as air is used as working medium to achieve refrigeration. Vortex tube has been used for many decades in various engineering applications. The vortex tube is interesting for new energy and refrigerating engineering as an experimental object with high development potential and as industry product with a quickly widening, unique combination of technological and operation properties Because of its compact design and little maintenance requirements, it is very popular in heating and cooling processes.

II. EXPERIMENTAL SET UP

The schematic of the experimental set-up used for the present investigation is shown Fig. 4.1. The set-up consisted of the following components.

1) Vortex tube
2) Spinner
3) Pressure gauge
4) Magnetic bench
5) Flexible pipe
6) Thermocouples.

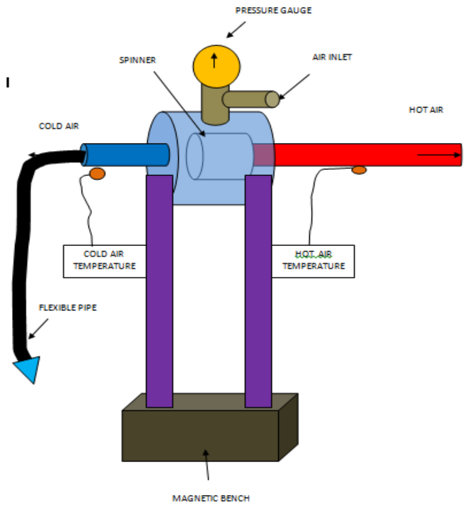

Figure1. Experimental Set-up

III. EXPERIMENTAL PROCEDURE

The vortex tube is an expansion type device, in which both the pressure and temperature are reducing. The vortex tube consists of hot end, cold end and inlet air end.

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The testing was performed by supplying compressed air which is a medium. Condition considered during testing based on opening and closing of regulating valve, which is placed at hot end. The readings of vortex tube are measured in terms of pressure (kg/cm^2), hot end and cold end temperature (^{0}C). This parameter comes under in structure parameter of vortex tube.

During an operation when pressurised air supply through a vortex tube, it comes from hot end and cold end. With period of time pressure inside of tube goes on decreasing and it's directly effect on hot end temperature which is increase and cold end temperature is decrease. Following are the cases considered during a testing.

1. When Hot end valve fully closed (90^0)
2. When valve partially closed (60^0)
3. Valve at middle (45^0)
4. When valve Partially open (25^0)
5. Hot end valve fully open (0^0)

IV. RESULT AND DISCUSSION

The facility is developed to carry out the experimental investigation of the vortex tube using different working conditions like pressure & at different valve openings. The vortex tube is tested with all these conditions. A series of experiments are performed to evaluate the performance of the system and to optimize the vortex tube.

Experiments are carried out under following conditions.

- Inlet pressures range: 1 bar- 5 bar
- Working substance: air

It can be seen from the figure 2 that,

- Air was not allowed to flow through one end sharp drops in cold end temperatures reported suggestive in sudden drop in enthalpies as enthalpies are function of pressure straightway.

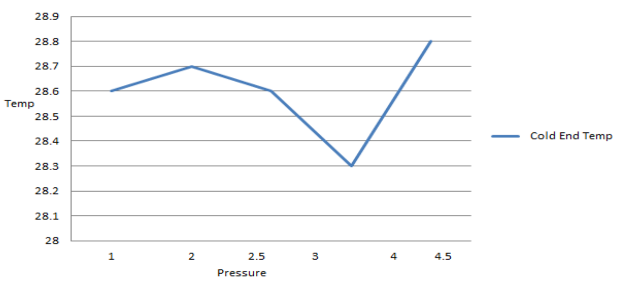

Figure 2.When hot end valve fully closed (90^0)

It can be seen from the figure 3 that,

- Beyond pressures above 3.5 bar hot end trends are completely different which is typical of compressibility effects and bulk modulus of air comes into action as a result of valve nearly closed condition.

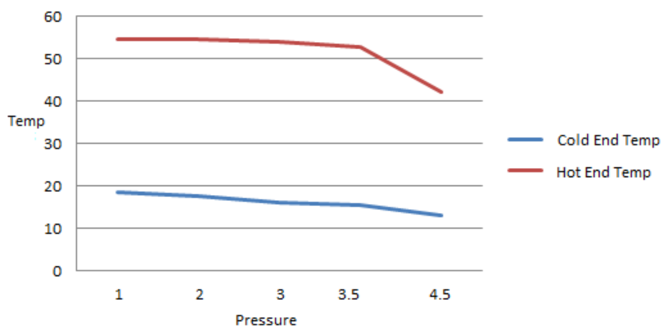

Figure 3.When hot end valve fully closed (60^0)

It can be seen from the figure 4 that,

- Average temperature is of log mean kind like in heat exchangers for pressure range between 1 bar to around 3.5 bar , thereafter trends become linear suggestive of unsteadiness as usual which is typical of vortex tubes as well.

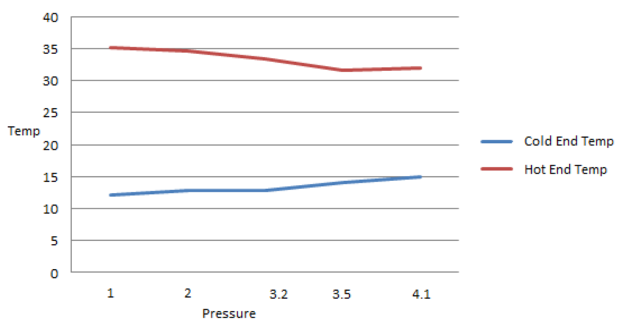

Figure 4.When hot end valve fully closed (45^0)

It can be seen from the figure 5 that,

- For partially open case Fluctuations in drop in temperatures of tube are similar but trends for cold and hot end are little but reversed. For pressures between 3 and 4.5 bar or kg/ cm^2 trends are in consistent and behavior is unsteady. Unsteady state heat transfer effect augments. Such behavior is typical of vortex tubes in refrigerant applications.

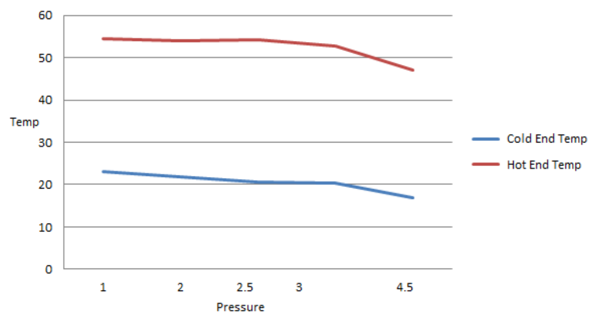

Figure 5.When hot end valve fully closed (25^0)

It can be seen from the figure 6 that,

- Unsteadiness is more for the case shown below and as a result of the air was allowed to flow from both the ends. Temperature is completely unsteady as has been illustrated through Figure. Thus with lower pressures even incompressibility effects are supressed with valves at fully open condition.

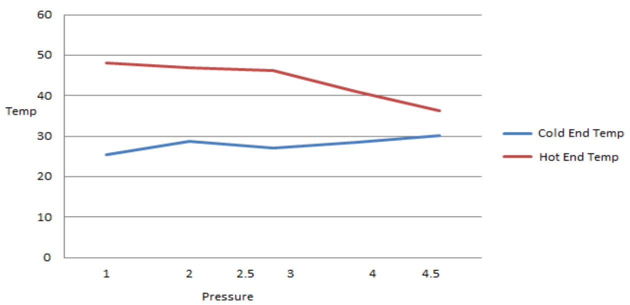

Figure 5.When hot end valve fully closed (0^0)

V. COCLUSION

Vortex tube refrigeration is one of the non-conventional methods to develop cooling effect. It is a simple tube where compressed gas enters tangentially which leads to formation of vortex.

The formation of vortex separated the gas into two streams, cold and hot by exchanging energy and cooling is achieved. Performance of the vortex tube depends on the parameters such as L/D ratio, gas pressure, cold mass fraction and the type of the gas. An experimental study is carried out to measure the performance of the vortex tube.

In the theses outlined above

Following conclusions can be drawn.

1. Vortex tube is highly sensitive to valve opening
2. For initial valve closure sudden drops in temperatures are observed
3. Pressure range , generally from more than 3 bar is highly important for commercial applications
4. Enthalpy effects are dominant for valves nearly at open positions
5. Steady state and unsteady state heat transfers augments with respect to valve positions, which should be circumvented in future work properly and is challenging.
6. Incompressibility effects are playing key role when valves are at nearly closed position/s.
7. Simulations runs are consistent over the experimentally observed facts but still more physical analysis is required as interacting parameters are dominant.
8. Experiment shows that by increasing the number of nozzles the temperature difference between hot end and cold end also increases. Also by increasing the inlet pressure the cold outlet temperature decreases simultaneously that is temperature difference increases

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