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A REVIEW ON EXPERIMENTAL INVESTIGATION OF VORTEX TUBE WITH DOUBLE INLET NOZZLE& FLAT FACE CONICAL VALVE

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ABSTRACT:

Vortex tube is non-conventional system; in these natural substances e.g. air used is for refrigeration. Vortex flow phenomenon complex and compressible phenomenon. The solution of turbulent vortex flow is very difficult. In view of this an in house experimental facility is developed and which facilitate the testing on double nozzle vortex tube at various operating and design parameter such as L/D ratio, cold mass fraction ratio, operating pressure and cold end orifice diameter .In this study, past investigation of the design criteria of vortex tubes were overviewed and the detail summary is while designing it vortex tubes were classified and the type of them was described. All criteria on the design of vortex tubes were given in detail using experimental and theoretical results from the past until now. Finally optimum design of them is summarized.

KEYWORDS: vortex tube; cold mass fraction; nozzles; control valve angle; cop; geometrical parameters.

INTRODUCTION:

The vortex tube is a simple device which takes compressed air and splits it into two air streams i.e. cold and hot air streams. Vortex tube consists of hollow tube known as vortex chamber. Vortex chamber can be a straight, divergent or convergent tube. Vortex tube also consist of cold end with one or more no. of nozzles, hot end with hot air control plug [1]. Cutaway drawing of a counter-flow vortex tube is shown in Figure 1. Compressed air enters at one end of the vortex chamber through the air inlet. The air pressure energy is converted to velocity and air forms a vortex at the inside periphery of vortex chamber and the inner layers of air press upon the outer layers by centrifugal force and compress the air at outerperiphery, which travels to the other end of chamber where the flow is restricted by a hot end control valve and flow reversal takes place.

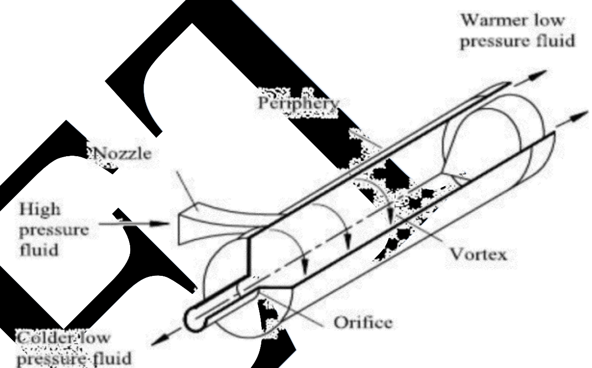

Figure 1 Cutaway of vortex tube [1]

The temperature of outer side rises and air at the inner layer gets bigger and it results in the dip in temperature of inner layers. Valve on hot end it is possible to vary the amount of the incoming air that leaves through the cold exit, known to as the cold fraction. The streams of air leaving through the hot and cold ends of the tube are at higher and lower stagnation temperature, respectively, than the air entering the nozzle. This effect is referred to as the temperature separation effect or energy separation [1].

CLASSIFICATION OF VORTEX TUBE:

There are two types of flow paths in vortex tubes such as parallel flow and counter flow. In Figure 2 and Figure 3 the schematic representation of the parallel flow and counter flow vortex tube is shown.

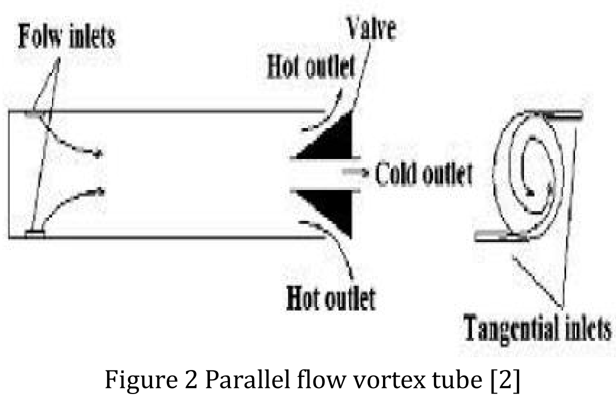

Figure 2 Parallel flow vortex tube [2]

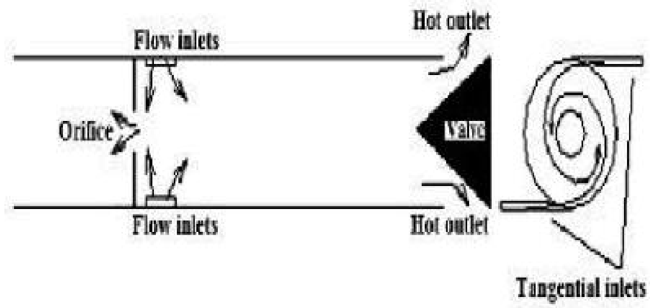

Figure 3 Counter flow vortex tube [2]

The energy separation of counter flow vortex tube is shown in Figure 3.The working principle of the counter flow vortex tube can be explained as follows: Working fluid is tangentially introduced into the vortex tube through the nozzles, makes a circular movement inside the vortex tube at high speeds, due to circular cross section of the tube, and depending on its inlet pressure and speed. The cooled fluid then leaves the vortex tube by adjusting with the main flow direction; however, heated fluid leaves in the direction of main tube [2].

IMPORTANT DEFINITIONS:

This section presents some important terms commonly used in study of RHVT.

COLD MASS FRACTION: It is given as the ratio of mass of gas leaving through cold exit to the total mass of gas entering through the nozzle.

$$\mu = m_c / m_i$$

COLD AND HOT END TEMPERATURE DISCREPANCIES: Cold end temperature is stated as the difference between temperature of gas at inlet and gas at cold exit.

$$\Delta T_c = T_i - T_c$$

Hot end temperature difference is defined as the difference between temperature of gas at inlet and temperature of gas at hot exit.

$$\Delta T_h = T_h - T_i$$

COEFFICIENT OF PERFORMANCE (COP): It is defined as the ratio of refrigerating or cooling effect obtained to the work input supplied. COP of vortex tube can be given as:

$$COP = \eta_{ab}\eta_c (p_a/p_i)^{(\gamma-1)/\gamma}$$

PARAMETRIC STUDY OF THE VORTEX TUBE:
L/D (LENGTH TO DIAMETER) RATIO

M.H. Saidi et al. [3] conducted experiments to investigate the effect of geometrical parameters on the operational characteristics of vortex tube, vortex tubes with different tube sizes. Figure 7 show variation of efficiency with L/D of vortex tube for μ 0.55a and nozzle with 4 intakes. Conclusion of that study is that for L/D ≤ 20 energy separation decreases leading to decrease in cold air temperature difference and efficiency decreases as well. For L/D ≥ 55:5, the variation of efficiency with L/D is not considerable. Consequently, the optimum value of L/D is within the following ranges 20 ≤ L/D ≤ 55.5 [3].

NUMBER OF INLET NOZZLE:

Orhan Kirmaci et al. [2] Studied the effects of the orifice nozzle number and inlet pressure on the heating and cooling performance of counter flow Ranque–Hilsch vortex tube using air and oxygen as a fluid experimentally. A counter flow Ranque–Hilsch vortex tube with (L=150 mm, D=10 mm) L/D ratio equal to 15 was used. Five different orifices with different nozzle numbers (2, 3, 4, 5, and 6) have been manufactured and used in the experiments.

Kemal polat [5] performed experiments to investigate the effect of nozzle number on the performance of vortex tube. He conducted experiments with 5 different nozzle no.(2, 3, 4, 5, and 6) with air, O2, N2 and Ar as working fluid, from his study it can be concluded that as the nozzle no. increases cold mass temperature difference decreases i.e. tube performs best with 2 number of nozzles.

COLD ORIFICE DIAMETER:

Pongjet Promvonge et al. [6] performed experiments on vortex tube with cold end orifice diameters ranging from 0.4D to o.9D (6.4mm - 14.6mm).The decrease in temperature in the cold tube was found to be 18, 19, 15, 14, 12, and 10°C for using cold orifice diameter of 0.4D, 0.5D, 0.6D, 0.7D, 0.8D and 0.9D at the cold mass fraction of 0.364, 0.375, 0.381, 0.378, 0.373, and 0.372, respectively. The cold orifice diameter of 0.5D yielded the highest potential of temperature reduction in the cold tube than the others. Using the cold orifice diameter ranging from 0.6D to 0.9D (bigger than that of

0.5D) would allow some hot air in vicinity of the tube wall to exit the tube with the cold air. Both the hot air and cold air as flowing out were mixed together which further affected the cold air to have higher temperature. On the other hand, for a small cold orifice diameter of 0.4D, has a higher back pressure and makes the temperature reduction at the cold tube lower.

J prabhakaran et al. [7] Made attempt to design and test simple counter flow vortex tube by investigating the effect of orifice diameter. Diameter of vortex tube D= 12 mm; Length of vortex tube L= 240 mm (L/D =20). Diameter of orifice selected Do = 5 mm, 6 mm and 7 mm, Diameter of nozzle DN = 3 mm, No of nozzle= 1, Material= Stainless steel, Inlet pressure as 4 to 7 bar. At low pressure (4 bar) the entire orifice will perform more efficiently. But at higher pressure the orifice with 6mm diameter performs good and the maximum cold mass temperature difference is obtained as 26.50 at 7 bar. The maximum hot mass temperature difference is obtained as 19.80 at 7 bar with orifice of 7 mm diameter. At low pressure (4 bar) the COP Carnot is maximum as 10.5 with orifice plate of 7 mm diameter. The diameter of the orifice influences the expansion that takes place in the vortex chamber. When the diameter of the orifice is 6 mm (0.5 D), it produces best cooling effect. When the diameter of the orifice is 7 mm (0.6 D), it produces best heating effect. When the orifice diameter is 5 mm, the energy separation is affected and temperature difference is decreased. It shows that the diameter of the orifice is an important factor for the energy separation.

NOZZLE DIAMETER:

J prabhakaran et al. [7] performed experiments to investigate the effect of Nozzle diameter on the energy separation in the vortex tube. Nozzles with different diameter (with DN = 2mm, 3 [illegible] and 5 mm) were experimented and he found that tube performs best with the nozzle diameter of 3mm.

HOT END VALVE ANGLE:

BurakMarkal et al. [illegible] Conducted experiments to investigate effects of the conical valve angle on thermal energy separation in a counter-flow vortex tube. Four different values of the valve angles 30°, 45°, 60° and 75°.He tested the effect of the valve angle for various values of the inlet pressure (3, 4 and 5 bar (absolute) and he concluded that effect of valve angle is generally negligible. However, for small values of L/D, this effect becomes considerable. He disclosed that it's better to use the conical valves with a smaller angle in order to improve the performance of the vortex tubes with smaller L/D. Conical valve angle of 30° valve gives better results.

K Dincer et al. [9] performed experiments to study effects of position, diameter (5, 6, 7, 8 mm) and angle of a mobile plug, located at the hot outlet side in a Ranque–Hilsch Vortex Tube (RHVT), were determined experimentally for best performance. Conical valves with angles 30°, 60°, 90°, 120°, 150°and 180° were manufactured. From the experimental results it can be concluded that the [illegible] T values are observed with the plug which has a tip angle of 30° or 60°.

OBSERVATION:

Above review reveals that best performance geometrical parameters are as follows:

1. Length to diameter ratio is 20-30.
2. As number of nozzles increases, turbulence increases, [illegible] nozzlesgives best results [5] [2].
3. C[illegible]rifice diameter 5 [illegible] 7 mm, Best results are found with [illegible] orifices.
4. For orifice below 5mm diameter back pressure causes lower temperature reduction due to expansion and above 7mm hot air near the tube wall mixes with cold air thereby decreasing the cold air temperature drop [7] [10].
5. Nozzle diameter 3mm [7]
6. Conical valve angle 30°-60° [9]

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