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# Effect of Geometric Modifications on the Performance of Vortex Tube - A Review

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**ABSTRACT**
The vortex tube is device, which produces hot and cold air streams simultaneously at its two ends from a source of compressed air without any moving part. Literature review of this paper is to understand the effect of various parameters like inlet pressure of air, number of nozzles, cold orifice diameter and hot end valve angle on the performance of vortex tube**.** Also by the literature review it is clear that there is no theory so perfect, which gives the satisfactory explanation of the vortex tube phenomenon. Due to this reason researcher conduct the series of experimentation to understand the effect of various parameters mentioned above on the performance of vortex tube.
***Keywords*** – Experiment, Geometric, Modification, Performance, Vortex tube.

## I. Introduction

Vortex tube is a simple device, which can cause energy separation. It consists of nozzle, vortex chamber, separating cold plate, hot valve, hot and cold end tube without any moving parts. In the vortex tube, when works, the compressed gaseous fluid expands in the nozzle, then enters vortex tube tangentially with high speed, by means of whirl, the inlet gas splits in low pressure hot and cold temperature streams, one of which, the peripheral gas, has a higher temperature than the initial gas, while the other, the central flow, has a lower temperature. Vortex tube has the following advantages compared to the other commercial refrigeration devices: simple, no moving parts, no electricity or chemicals, small and lightweight, low cost, maintenance free, instant cold air, durable because of the stainless steel and clean working media, temperature adjustable. On the other hand, its low thermal efficiency is a main limiting factor for its application.

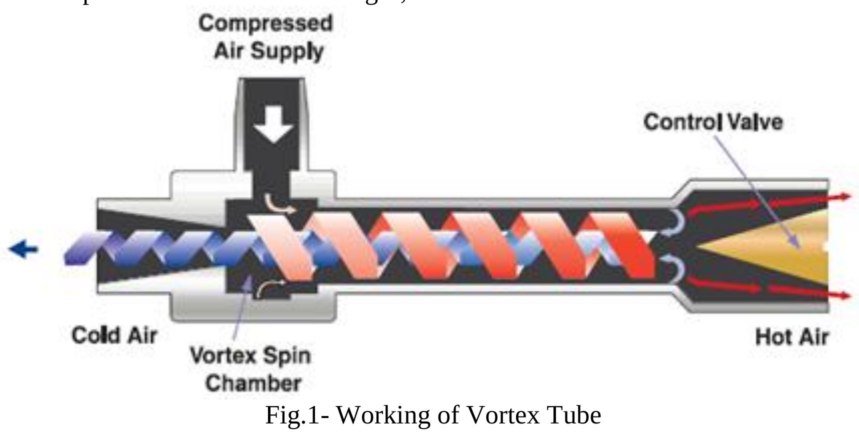


Fig.1- Working of Vortex Tube

Hilsh firstly studied the mechanism of vortex tube and claimed that internal friction lead to the energy separation of vortex tube[1]. Kassener and Knoernschild proposed that the conversion of an initially free vortex into a forced vortex result in a radial redistribution of energy [2]. The theory was supported by the study of some researchers. Stephan and Lin [3] proposed Goertler vortices produced by tangential velocity as a main driving force for the energy separation in the vortex tube. A different theory was developed by Mischner and Bespalov [8]. They explained the energy separation mainly caused by entropy generation in vortex tube.

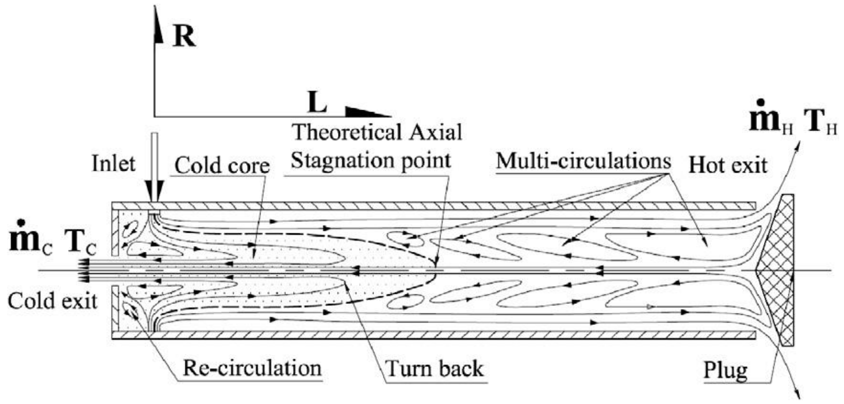


Fig. 2-Structure of a counter-flow vortex tube.

Yunpeng Xue et al. studied experimentally the flow behavior of fluid inside a counter-flow vortex tube aiming to locate the dominant reason for the temperature separation in a vortex tube as shown in fig.2. Variable geometrical parameters have been tested in the experiments, and their effects on the temperature separation in the vortex tube are presented and discussed in his work [9].

## II. Types of Vortex Tubes

There are two classifications of the vortex tube. Both of these are currently in use in the industry. The more popular is the counter-flow vortex tube (Figure 2). The hot air that exits from the far side of the tube is controlled by the cone valve. The cold air exits through an orifice next to the inlet.

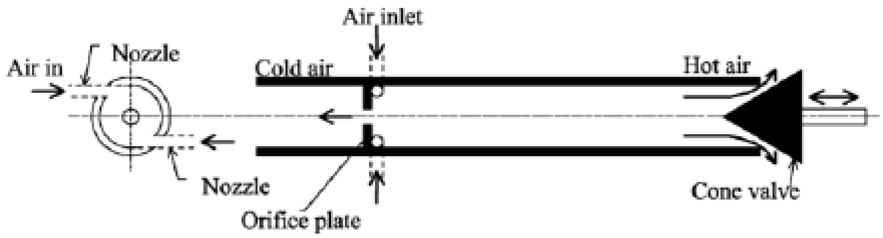


Figure 2: Counter-ow vortex tube

On the other hand, the uni-flow vortex tube does not have its cold air orifice next to the inlet (Figure 3). Instead, the cold air comes out through a concentrically located annular exit in the cold valve. This type of vortex tube is used in applications where space and equipment cost are of high importance. The mechanism for the uni-flow tube is similar to the counter-flow tube. A radial temperature separation is still induced inside, but the efficiency of the uni-flow tube is generally less than that of the counter-flow tube [11].

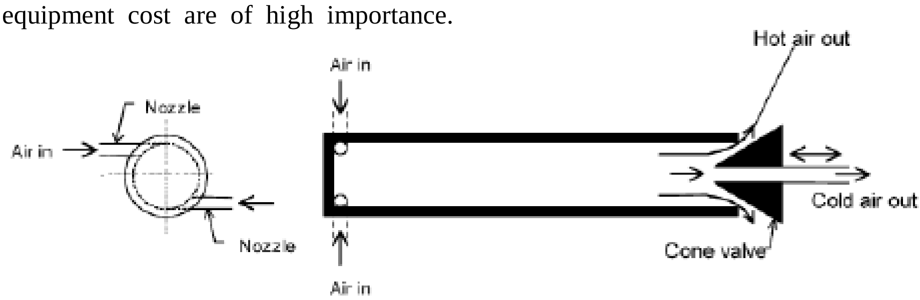


Figure 3: Uni-flow vortex tube

## III. Effect of Various Parameters On Vortex Tubes

Y.T. Wua,* et al proposed three innovative modifications of configuration of vortex tube in Nozzle intake, hot end pipe diffuser of vortex tube. An improved nozzle, Nozzle of equal gradient of Mach number was designed by the author. A new nozzle with equal Mach number gradient and an intake flow passage with equal flow velocity were used in the modified vortex tube. The experimental results indicate that the cooling effect of the improved nozzle is about 2.2 °C lower than that of the nozzle with normal rectangle and even 5 °C lower than that of the nozzle with Archimedes' spiral. A diffuser was designed and installed between the outlet of vortex tube and hot valve aiming to reducing the peripheral speed to zero within very short pipe and greatly reduce the ratio of length to diameter. The experimental results indicate that the cooling effect of the vortex tube with diffuser is up to 5 °C lower than that without diffuser. A vortex tube which combined various measures was developed, and the experiment with air as medium was carried out as well. The developed vortex tube is not only superior to the conventional vortex tube but also is superior to that made in other country, especially under big cold mass flow ratio.

Sachin U. Nimbalkar et al. studied the effect of cold orifice diameter on the energy separation efficiency of the vortex tube. His experimental results indicate that there is an optimum diameter of cold-end orifice for achieving maximum energy separation. It was observed that for cold fraction ≤ 60%, the effect of cold end orifice diameter is negligible and above 60% cold fraction it becomes prominent. The results also show that the maximum value of performance factor was always reachable at a 60% cold fraction irrespective of the orifice diameter and the inlet pressure. Our claim is that the cold fraction is the crucial parameter to relate the flow structure inside the vortex tube to its performance factor [4].

Figure 1 shows the setup for the experiments done by Sachin Nimbalkar. The purpose of this study was to examine the effect of the cold end orifice diameter on the overall energy separation of the vortex tube. Different generators with varying cold-end orifices were manufactured in the lab as shown in Fig. 2 and tests were conducted using a commercially manufactured vortex tube for different inlet mass flow rates 0.45, 0.68 and 0.82 kg/min.[4]

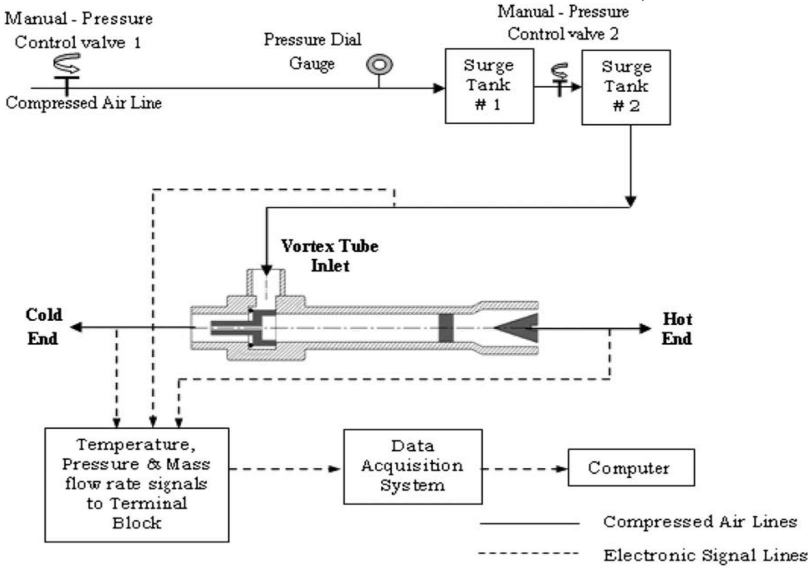


Fig. 1. Schematic of the experimental apparatus used by Sachin U. Nimbalkar et al.

**1. Effect of Cold Orifice Diameter On performance of vortex tube**

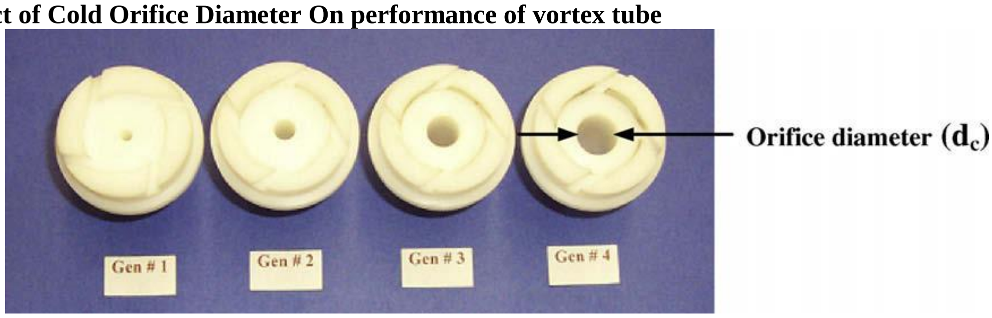


**Fig. 2. Lab manufactured generators with varying orifice diameter.**

Figure 2 shows the different orifice diameter used by Sachin U. Nimbalkar et al.
In Fig. 3, energy separation efficiency is plotted against the cold fraction for various cold end orifice diameters [$d_r$ = ($d_c$/D) = 0.18– 0.66] at inlet mass flow rate of 0.45 kg/min.

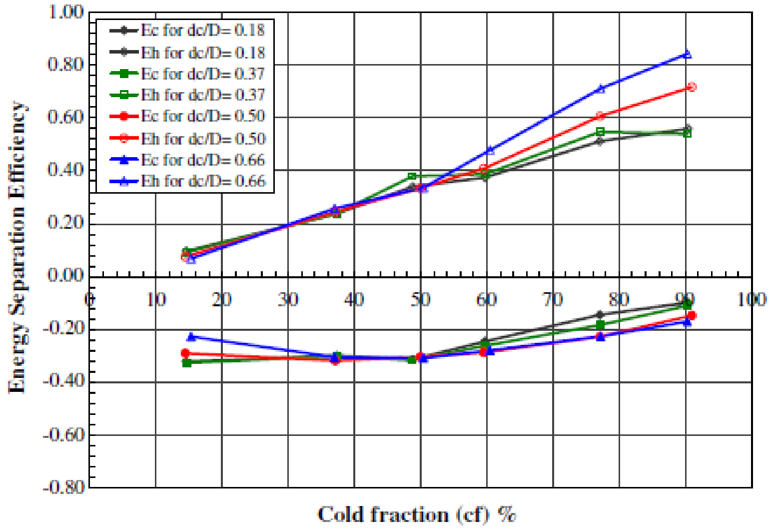


Fig. 3. Effect of orifice diameter on the energy separation.

From the Fig. 3 it was observed that for cold fraction ≤ 60%, the effect of cold end orifice diameter is negligible and above 60% cold fraction it becomes prominent. The results also show that the maximum value of performance factor was always reachable at a 60% cold fraction irrespective of the orifice diameter and the inlet pressure.

0Fig. 4 shows the dependence of energy flux separation efficiency of the vortex tube on the cold fraction with the orifice diameter at the inlet mass flow rate of 0.45 kg/min. As discussed earlier, the effect of inlet mass flow

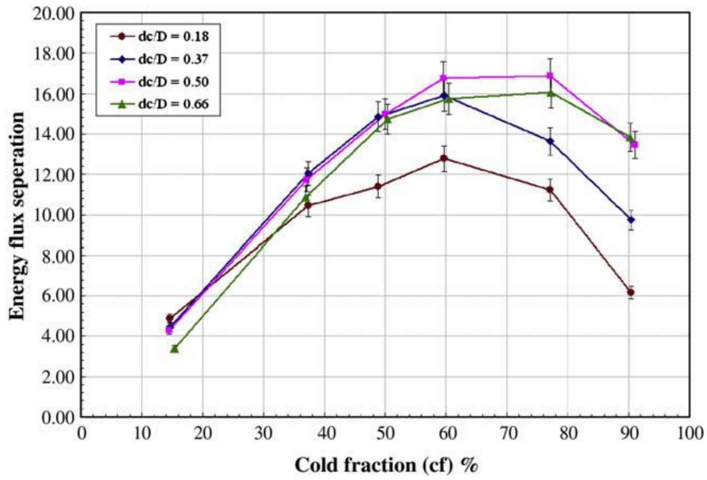


Fig.4. The effect of orifice diameter on the energy flux separation efficiency ($m_i$ = 0.45 kg/min). Error bars in the graph indicate 5% of experimental error.

rate is washed out because of its presence in the cold fraction. The results are showing that below 60% cold fraction the energy fluxes are varying almost linearly and the effect of orifice diameter is very insignificant. Beyond 60% cold fraction, the effect of orifice diameter is dominant. Firstly, energy flux separation efficiency is dropping with an increase in cold fraction and secondly for constant cold fraction it is increasing with orifice diameter. Hence, it can be concluded that while operating the vortex tube for cold fraction above 60%, selecting larger orifice diameter will give better energy flux separation efficiency.

K. Dincer et al. studied the effects of position, diameter (5, 6, 7, 8 mm) and angle (30°–180°) of a mobile plug, located at the hot outlet side in a Ranque–Hilsch Vortex Tube (RHVT), were determined experimentally for best performance. From the presented results, it can be seen that the most efficient (maximum ΔT ) combination of parameters is obtained for a plug diameter of 5 mm, tip angle of 30° or 60°, by keeping the plug at position L, and letting the air enter into the vortex tube through 4 nozzles. Increasing the inlet pressure beyond 380 kPa did not bring any appreciable improvement in the performance [5].

**2. Effect of Number of Nozzle Used**

Dincer et al. used the experimental setup shown in Fig. 5. Dincer et al. conducted experiment by using different number of nozzles. Fig. 6 shows the number of nozzles used.

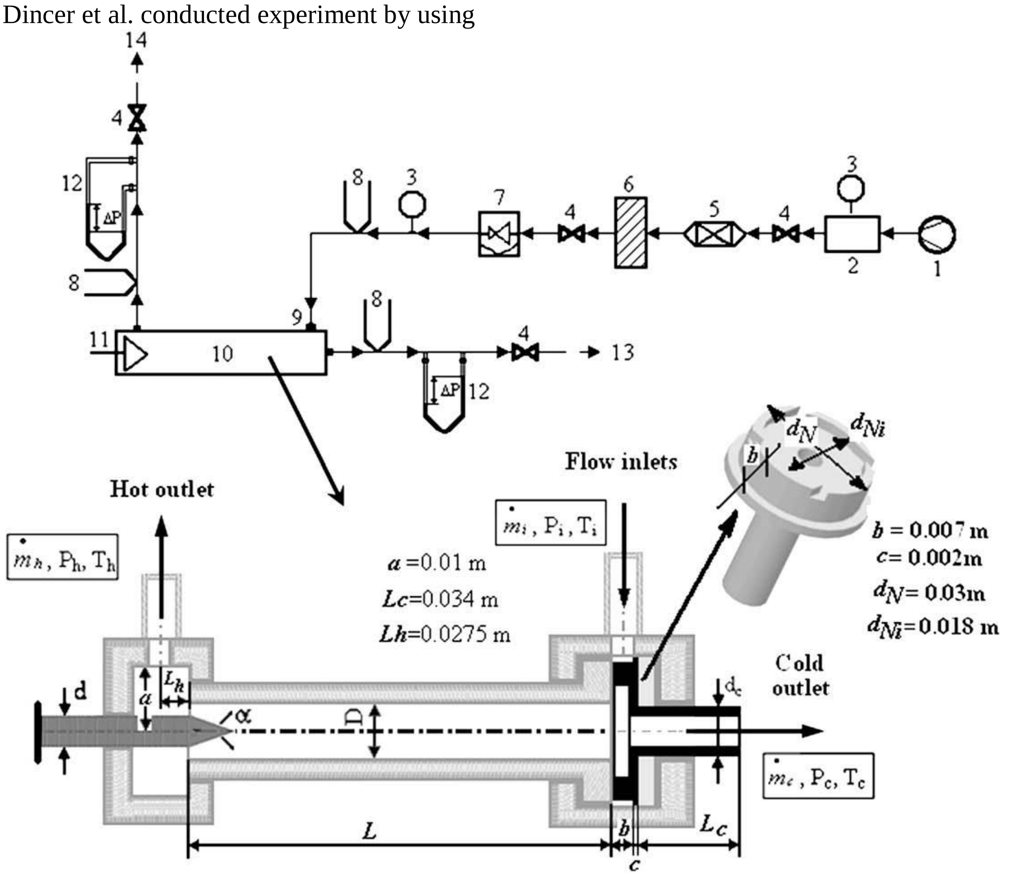


Fig. 5 – Schematic diagram of the experimental setup. 1. Compressor, 2.pressure tank, 3. pressure gauge, 4. valve, 5. Cooling and dehumidifying unit, 6. filter, 7. pressure regulator, 8. thermo-couple, 9. nozzle, 10.Ranque–Hilsch vortex tube, 11. plug, 12. manometer, 13. cold output, and 14. hot output.

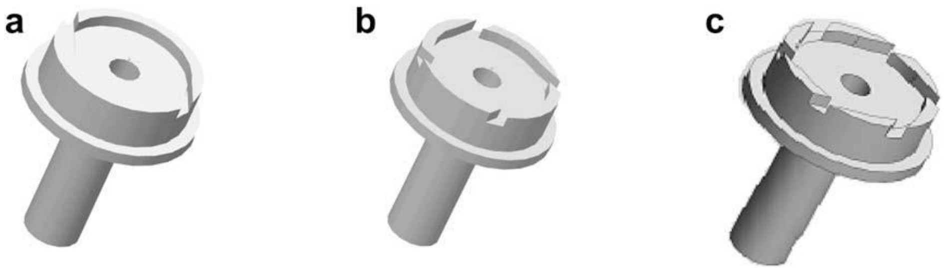


Fig. 6 – Nozzles used in experiments: (a) 2 nozzle, (b) 4 nozzle, and (c) 6 nozzle

Fig. 7 shows the effect of 2, 4, and 6 nozzles on the performance of the vortex tube, when the operating pressure is increased. An increase in the pressure at the entrance of the vortex tube results in an increase in the performance of the vortex tube with 2, 4, 6 nozzles. The best performance is obtained with the vortex tube which has 4 nozzles.

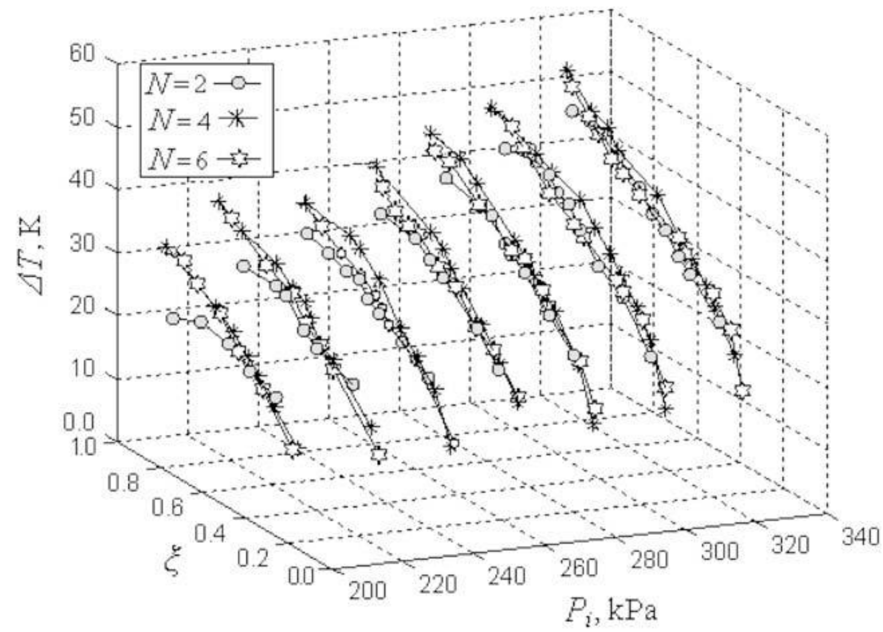


Fig. 7 – The variation of ΔT with Pi for different values of ξ,
N = 2, 4, 6; d = 5 mm, α = 60°, for L.

**3. Effect of Hot End Valve Angle on Performance of Vortex Tube**

Fig. 8 shows the effects of angle at the tip of the plug for 30°, 60°, 90°, 120°, 150° and 180° on the performance of the vortex tube. When the experimental data are assessed, it is found that the biggest ΔT values are observed with the plug which has a tip angle of 30° or 60°.

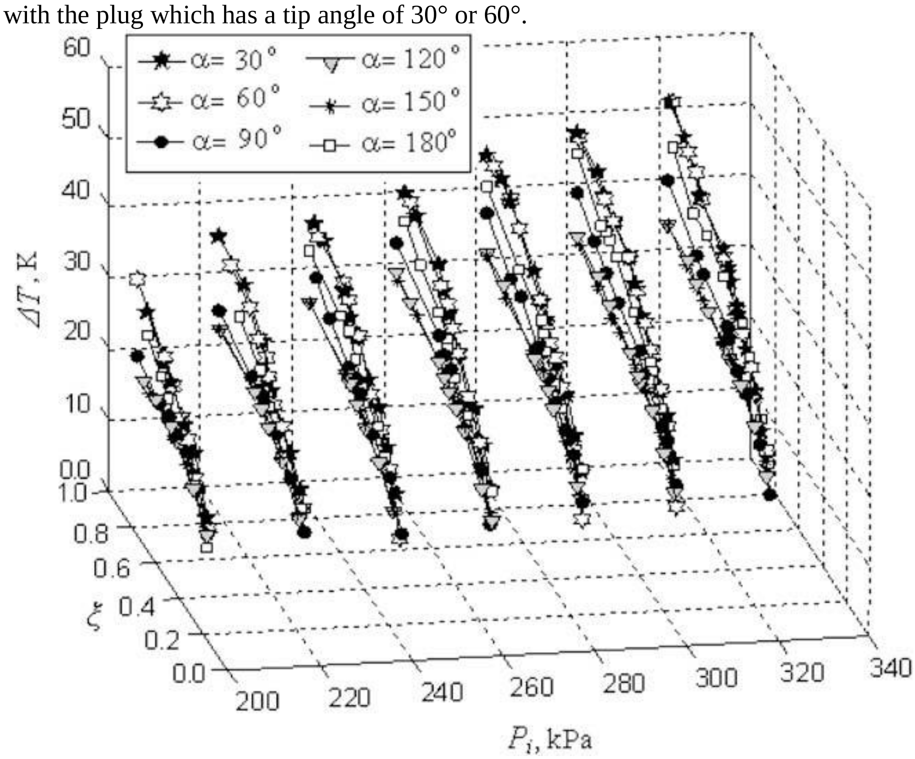


Fig. 8 – The variation of ΔT with Pi for different values of ξ, D = 5mm; N = 4; for L and α = 30°, 60°, 90°, 120°, 150°, 180°.

**4. Effect of Inlet Air Pressure on Performance of Vortex Tube**

Fig. 9 shows the variation in the temperature difference with different values of inlet air pressure and cold air mass fraction. The pressure at the entrance of the vortex tube was increased from 200 kPa to 420 kPa by increments of 20 kPa. Hence effect of the inlet pressure of the vortex tube

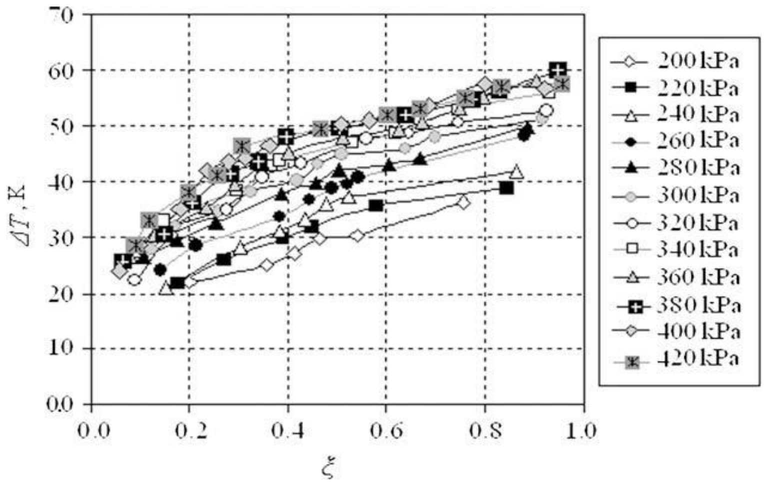


Fig. 9 – The variation of ΔT with Pi for different values of ξ,
N = 4; d = 5mm and α = 30° for L.

on the tube's performance was experimentally studied. When Fig. 9 is examined, it can be seen that the ΔT constantly increases from 200 kPa to 380 kPa, but the increase is less significant between 380 kPa and 420 kPa for the geometry and dimensions of the vortex tube employed.

## IV. Conclusion

In this paper the some experimental analysis work studied which is done by various researchers. The experimental results indicate that there is an optimum diameter of cold-end orifice for achieving maximum energy separation. It was observed that for cold fraction ≤60%, the effect of cold end orifice diameter is negligible and above 60% cold fraction it becomes prominent. An increase in the pressure at the entrance of the vortex tube results in an increase in the performance of the vortex tube with 2, 4, 6 nozzles. The best performance is obtained with the vortex tube which has 4 nozzles. From the experimentation of K. Dincera et. al.it is found that the biggest ΔT values are observed with the plug which has a tip angle of 30° or 60°.

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