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Computational Fluid Dynamics Study on the Effects of L/D Ratio in a 2 stage Hot Cascade Vortex Tube

R. Madhu Kumar, N.V.V.S.Sudheer

Abstract*: The non-traditional vortex tube based cooling device consisting of non-moving elements so one can create hot-air and cold-air from supply of compressed air lack on influencing on environment. At this point, the greater high air-pressure is infused digressively into chamber with a high grade vortex float can be made so *one can be separate into two air streams, one as cold circulate and another as warm circulation. In the 2 stage hot cascade vortex tube, hot output of first vortex tube was associated with contribution of second vortex tube. In this study, the appearance of two-stage cascade hot vortex tube, with the length of diameter-ratio (L/D) of 10 and 15 with different pressures 8, 9, 10, 11, and 12 bars, on the basis of CFD results were investigated. The temperature deviation in between the hot inlet and outlet (ΔT_{hot}), cold outlet and the inlet (ΔT_{cold}) were investigated by using CFD software data. It was found that high temperature difference between the hot outlet and the inlet (ΔT_{hot}), cold outlet and the inlet (ΔT_{cold}) were obtained at L/D ratio 10 and pressure of inlet air was 12 bars.

Index Terms*: CFD; Hot Cascade Vortex Tube; L/D Ratio; Temperature.

I. INTRODUCTION

The vortex-tube, the other name is Ranque-Hilsch Vortex Tube (RHVT) is apparatus which generates isolated streams of hot and cold gasses from a compacted gas source. The vortex tube changed into invented quite by means of twist of fate in 1931 through G. Ranque, a French physics scholar, whilst research on vortex-pump as advanced, after that noticed hot-air laborious from cease and alternative for cold-air. The Ranque forget the observations on his pump and develop a small business form to exploit the ability as commercially for unique tool for generating cold and hot airs with non-requirement of any moving elements. Moreover, it fails and slipped into a insignificance till 1945 while R. Hilsch, a German Physicist broadly publishing the various publications.

A lot in advance, the exceptional 19th century physician, J. C. Maxwell proposed that because of the reality warm incorporates the development of atoms, we may one day be equipped for get warm and cool air from the indistinguishable instrument with the assistance of an "agreeable little evil presence” might compose and isolate the chilly & hot air-particles. Therefore, the vortex-tube has been eluded differently as the "Ranque Vortex Tube", the "Hilsch Tube", "Ranque-Hilsch Tube", and "Maxwell's Demon". Methods for any call, it is in current year acquired the basic, minimal & dependable effort by broad sort of several cooling concerns.

In this context, the high weighted air is infused extremely in vortex chamber by gulf spout; a whirling skim is defined in vortex chamber. Inbuilt vortex camber, exists the gas through cooling fumes promptly, some other component alluded as free-vortex twirls at hot-end, where it transforms by using various methods for making the control values as constraint vortex going from hot-end to lump-end. The heat-exchange takes distinct over the constrained vortexes at free-end by generating dual streams, one is warm and other is cooled stream at finish end. The vortex tube can be characterized into two kinds. While the cool fume is situated on the other angle from the ongoing fumes, it is named as counter-flow tube (Fig.1).

The sort of stream cold and hot air floats in reverse direction. On account of the warmth change taking zone between inverse headings it is exceptionally productive, sight-seeing and leaves the cool-air from the cylinder as the reverse closures of gulf. The respective sort is regularly used one utilized one. While the cool fumes are situated on the indistinguishable feature of the ongoing fumes, it is known as parallel-flow tube (Fig. 2). In this way, coast cold-air and warm-air accepts the way things are in indistinguishable course. Considerably less warmth exchange takes zone between a similar bearing streaming air streams along these lines, it is low effective. The cold & hot air leaves the one vortex-tube. Vortex tube can be utilized for a spot cooling or warming application.

As of late, the procedures of computational liquid elements (CFD) displaying have been created for more review and elucidation. N. F. Aljuwayhel [1] was studied. The internal and parametric variant vortex tube is studied by using CFD design. The energy-separate methodology and phenomena flow in a vortex tube by CFD model in [1]. These experiment results are attained at room temperatures from vortex-tubes functioning with compressed-air. V.A.Arbuzov [2] was observed Ranque effect and large-scale hydrodynamic structures in a vortex tube. In this V.A.Arbuzov [2] became observed first time massive-scale structures of the vertical double helix in a swirling Ranque drift. The states of the vertical twofold helix wind up pictured in genuine time with the guide of the system of Hilbert dichromatic separating.

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R. Madhu Kumar, [1]School of Mechanical Engineering, R.G.M.College of Engineering & Technology, Nandyal, Kurnool, Andhra Pradesh, India.

N. V. V. S. Sudheer, Department of Mechanical Engineering, RVR & JC College of Engineering,Guntur, Andhra Pradesh, India

The exploratory final product transformed into deciphered on that the most likely physical system for the spatial vitality detachment inside the fuel coast was gooey warming of gas as light limit layers at point of dividers layer of chamber with a cooling scheme at the center because of the development of an over the top vortex twist close to the pivot.

The author K.Dincer [8] have been investigated performances of RHVTs experimentally under three one-of-a-kind situations primarily based on pressure (inlet) and the mass glide ratio of cold movement for drifting the mass charge of the circulation. The first scenario is traditional RHVT. Second state of affairs is a series type RHVT. Here 3 RHVTs were used. Coming to third scenario which deals the six series formation of RHVT are used. It was located that the first-rate overall performance takes place at the 3rd scenario at different pressures. K.Dincer [10] investigated prototype implementation and performs an observation on hot series type Ranque-Hilsch vortex tube (RHVT) and energy analysis with regard to cold flow fraction. On this K.Dincer [10] were tested three RHVTs experimentally.

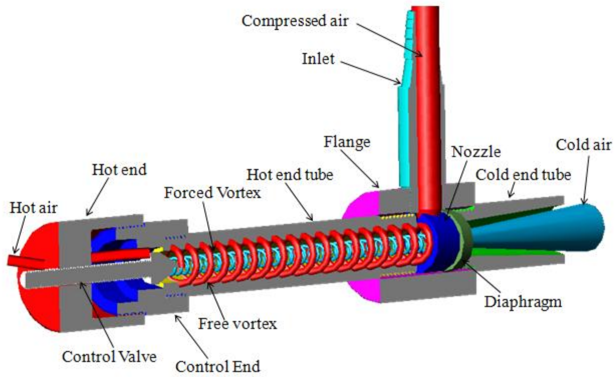

Fig. 1: Counter flow Vortex Tube

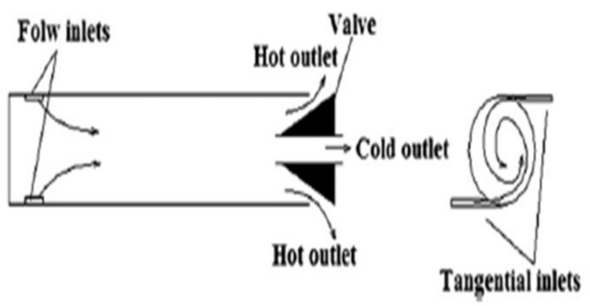

Fig. 2: Parallel flow Vortex Tube

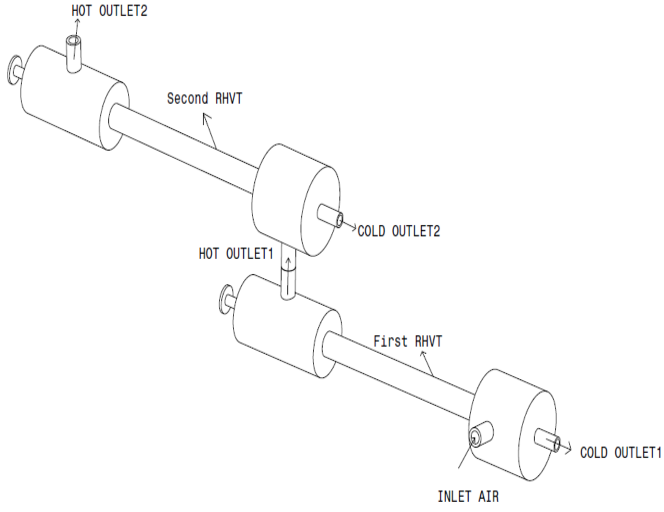

Fig. 3: Schematic diagram of 2 stage hot cascade vortex tube

The alternatives are hot cascade type RHVT. Inside the cascade hot type RHVT, first RHVT as hot yields which is associated with contribution of second RHVT. The acute differences on temperature ranges of hot inlet and outlet values (ΔT_{hot}) of cascade hot type RHVTs is higher priority than ΔT_{hot} values of formal (ΔT_{hot}). It is represented that, the cascaded type hot RHVT have more energy efficiency of hot-outlet over the formal RHVT. There are lots of studies in the several literature studies on RHVT as analytical, theoretical, and experimental. Some of the U. Behera [3], Y.Cao [5], Y. Casasa [6], S. A. Colgate [7], T. Dutta [11], S. Eiamsa-ard [12] T. Farouk [14] W. Frohlingsdorf [15], S.Y.Im [17], O.V.Kazantseva [18], V.Kırmaci [19], S.U.Nimbalkar [20], M.A.Rosen [22], M.H.Saidi [23], A.Secchiaroli [25], H.M.Skye [26], M.S.Valipour [27], and Y.Xue [28].

II. HOT CASCADE ARRANGEMENT

In this investigation ANSYS CFX 15.0 package is utilized for making the model of two stage hot cascade vortex tube. In these two vortex tubes was utilized. This two were hot series type vortex tube. In the hot cascade-vortex tube type, output of hot first tube is apprehend with the contribution of vortex tube-2 appeared on Fig. 3. Two tubes, with the diameter (internal) of 6.75 mm and a length in terms of ratio 10:15 is modelled and verified with 8, 9, 10, 11 & 12 bar pressure air. Nozzle cross-section area = 3.141 mm^2 and number of nozzle is 6. In these analysis temperatures was recorded at inlet, hot outlet 1, hot outlet 2, cold outlet 1 and cold outlet 2 by using CFD software.

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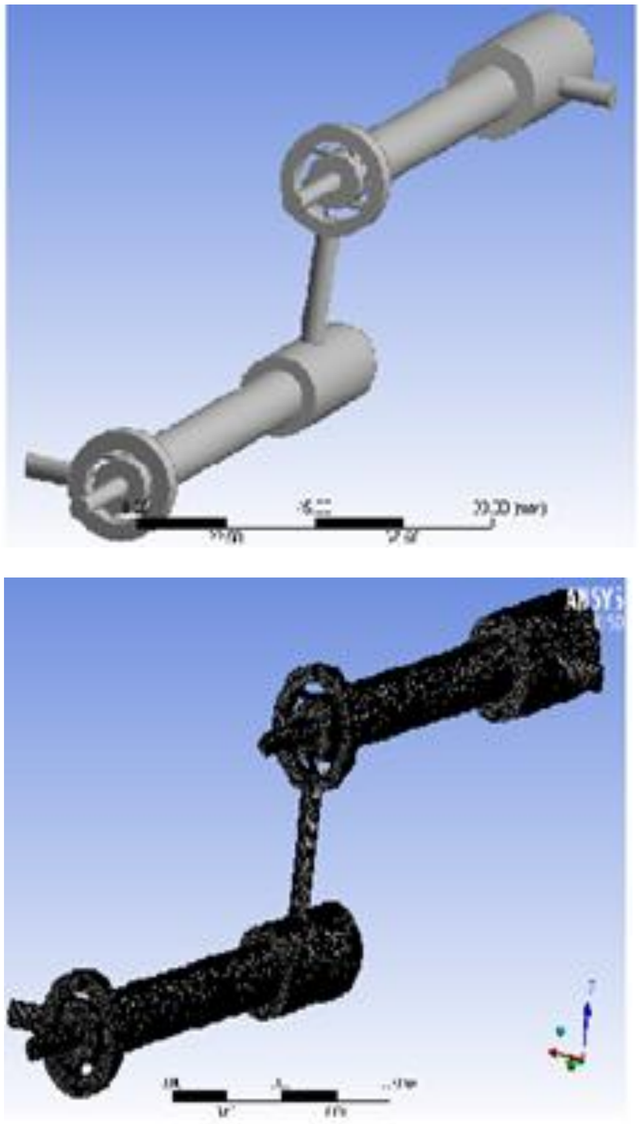

Fig. 4: Three-dimensional model of 2 stage hot cascade vortex tube

The following assumptions are made for this analysis in 2 stage hot cascade vortex tube system

- The vortex-tubes never transforms the heat with respective to surrounding natures. The various conditions of flow rate in a two-stage cascaded hot vortex tube can be assumed.
- Outlet/Inlet gas elements are considered as ideal.

Temperature difference at hot exit 1

$$\Delta T_{hot\ 1} = T_{hot\ outlet\ 1} - T_{inlet} \quad (1)$$

Temperature difference at hot exit 2

$$\Delta T_{hot\ 2} = T_{hot\ outlet\ 2} - T_{inlet} \quad (2)$$

Temperature difference at cold exit 1

$$\Delta T_{cold\ 1} = T_{inlet} - T_{cold\ outlet\ 1} \quad (3)$$

Temperature difference at cold exit 2

$$\Delta T_{cold\ 2} = T_{inlet} - T_{cold\ outlet\ 2} \quad (4)$$

III. RESULTS & DISCUSSION

In this study, the performance of two-stage cascaded hot cortex tube was analyzed by using ANSYS CFX 15.0 CFD software. In these two vortex tubes was used. This two were hot cascade vortex tubes. In the 2 stage hot cascade vortex tube, hot output of first vortex tube was connected to input of second vortex tube. In hot cascade vortex tubes were modelled as cold mass fraction (ξ) was controlled by the hot stream of the first and second vortex tubes ξ = 0.5 and the performance were analysed.

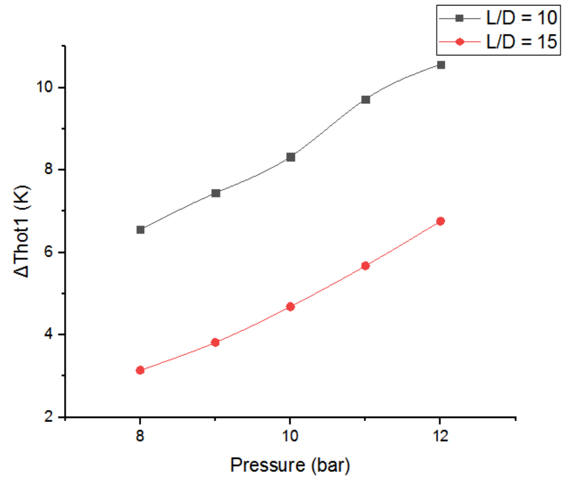

Fig. 5: $\Delta T_{hot\ 1}$ for different values of Pressure = 8 – 12 bar at L/D = 10 & 15

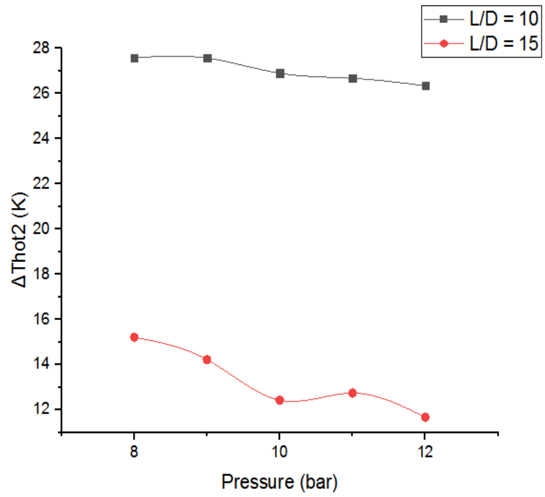

Fig. 6: $\Delta T_{hot\ 2}$ for different values of Pressure = 8 – 12 bar at L/D = 10 & 15

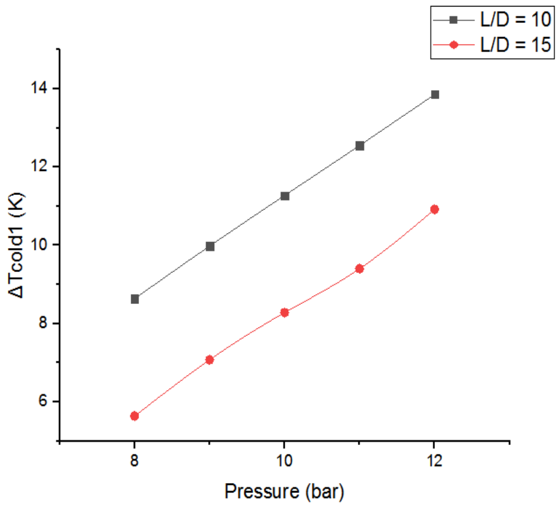

Fig. 7: $\Delta T_{cold\ 1}$ for different values of Pressure = 8 – 12 bar at L/D = 10 & 15

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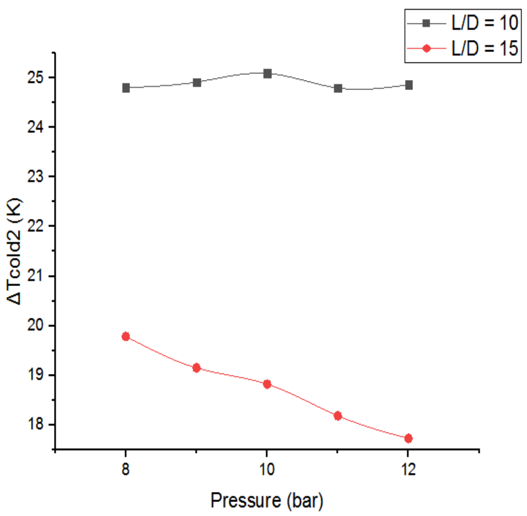

Fig. 8: $\Delta T_{cold\,2}$ for different values of Pressure = 8 – 12 bar at L/D = 10 & 15

In this study, critical evaluation is carried out based on attained CFD data results. The quantity of $\Delta Thot_{1}$, $\Delta T_{hot\,2}$, $\Delta Tcold_{1}$ and $\Delta T_{cold\,2}$ were calculated from Eqs. (1), (2), (3), and (4) respectively. Results shows the variations of $\Delta T_{hot\,1}$, $\Delta T_{hot\,2}$, $\Delta T_{cold\,1}$ and $\Delta T_{cold\,2}$ with respect to Pressure (P). According to the CFD results maximum values of $\Delta T_{hot\,1}$ = 10.6 K was obtained at L/D = 10 and P = 12 bar, $\Delta T_{hot\,2}$ = 26.3 K was obtained at L/D = 10 and P = 12 bar, $\Delta T_{cold\,1}$ = 13.9 K was obtained at L/D = 10 and P = 12 bar and $\Delta T_{cold\,2}$ = 24.9 K was obtained at L/D = 10 and P = 12 bar.

IV. CONCLUSION

The conclusions acquires from this concept is validated as follows,

- $\Delta T_{hot\,1}$ of 2 stage hot cascade vortex tube have been determined to 6.5 to 10.6 K for L/D = 10 and 3.1 to 6.8 K for L/D = 15 (Fig. 5). When Pressure (P) was changed from 8 to 12 bar, $\Delta T_{hot\,1}$ increased.
- $\Delta T_{hot\,2}$ of 2 stage hot cascade vortex tube have been determined to 27.6 to 26.3 K for L/D = 10 and 15.2 to 11.7 K for L/D = 15 (Fig. 6). When Pressure (P) was changed from 8 to 12 bar, $\Delta T_{hot\,2}$ decreased.
- $\Delta T_{cold\,1}$ of 2 stage hot cascade vortex tube have been determined to 8.6 to 13.9 K for L/D = 10 and 5.3 to 10.9 K for L/D = 15 (Fig. 7). When Pressure (P) was changed from 8 to 12 bar, $\Delta T_{cold\,1}$ increased.
- $\Delta T_{cold\,2}$ of 2 stage hot cascade vortex tube have been determined to 24.8 to 25 K for L/D = 10 and 19.8 to 17.7 K for L/D = 15 (Fig. 8). When Pressure (P) was changed from 8 to 12 bar, $\Delta T_{cold\,2}$ decreased.

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