Turkish Online Journal of Qualitative Inquiry (TOJQI)
Volume 12, Issue6, July , 7307- 7319

Research Article

Design Of Air Cooling Rhvt Device Using Unigraphics

Mohammed Hameeduddin Haqqani[a*], Mohammed Azizuddin[b], Syed Shuibul Qarnain[c] , Rajamahanti Surya Kiran[d]

[A]research Scholar, Department Of Mechanical Engineering, Career Point University , Kota- 325003
[B]department Of Mechanical Engineering, Deccan College Of Engg &Tech, Hyderabad -500001
[C]department Of Mechanical Engineering, Kalasalingam Academy Of Research And Education, Krishnankovil-626126

[C]department Of Mechanical Engineering, S.V.P Engineerining College, Visakhapatnam-530041

[*]Corresponding Author: Hameed6162@Yahoo.Com

Abstract
Rhvt A Ranque Hilsch Vortex Tube Is A Unique Thermo-Fluidic And Indisputable Device For The Purpose Of The Production Of The Hot And The Cold Temperatures Without Any Mechanical Aid. This Method Which Is Quiet Old In The Industry For The Application Of Centrifugal Swirling Of Two Fluids For The Purpose Of Separation Based On Density. This Method Of Cooling Utilizes Compressed Air To Be Injected Into A Turbulent Fixed Size Of Orifice Tube With Predefines Lengths And Diameters. In This Paper, An Attempt Is Being Made To Collect The Relevant And Proven Data From The Literature Surveys In Order To Collect The Suitable Dimensions For The Purpose Of Designing A New Efficiently Smaller Combined With Unique Features. Some Of The Reasons Attributed For This Kind Of Phenomenon Of Energy Separation Is Drop In The Temperature Due To The Sudden Expansion, Centrifugal Effect, Secondary Circulation And Friction. The Vortex Tube Could Be Used For The Purpose Of Spot Cooling Of Any Area And Machine Cooling Of A Moving Equipment Using An Industrial Compressed Air As The Source. The Use Of Compressed Air Makes The Device Less Susceptible For Breakdown Due To The Fact Being No Moving Parts Used In This System. There Is Also No Proven Facts Of Any Existence Of The Chemical Reactions Within The Vortex Tube.

Introduction

Ranque Hilsch Vortex Tube (Rhvt) Takes In The Compressed Air From The Air Compressor And Releases Hot Air From One End And The Cold End From The Other End. Generally Any Fluid Dynamics Takes Place Due To The Law Of Conservation Of Mass, Law Of Conservation Of Energy And Law Of Conservation Of Momentum.

In-Working, A Controlled Valve At Hot Air Exit Side (As Shown In The Fig-1) Is Positioned Inside The Tube Away From The Injection Point And Having The Dimensions Smaller Is Preferred Which Also Plays Key Role In The Functioning Of The Vortex Tube.

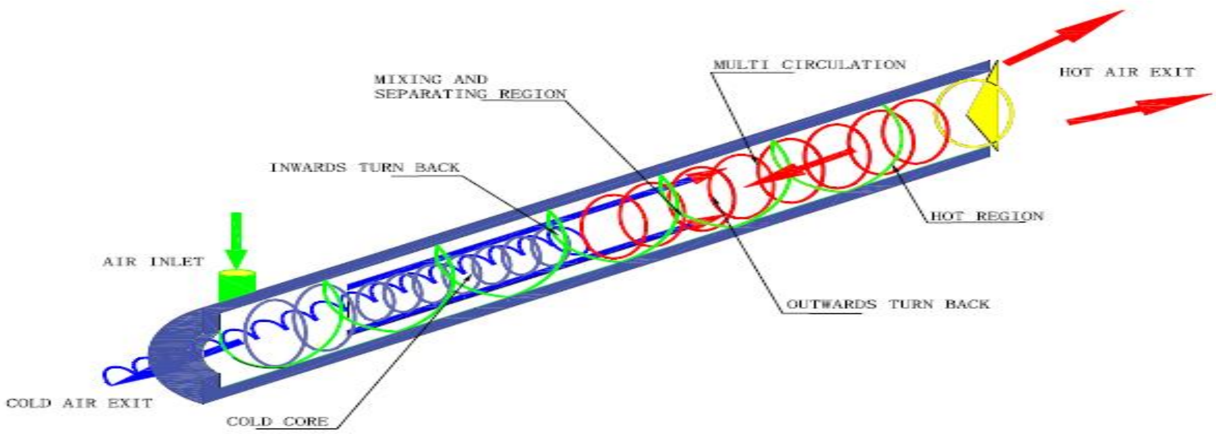

Fig-1 Explaining The Functioning Of The Vortex Tube Using A Simple Cut View

Procedure Of Working Of A Vortex Tube Is As Explained Below:

(a) Enter The Compressed Air Into The Nozzle.

(b) The Expanding Air With A High Velocity Creates A Vortex Flow Or A Spiral Flow And Thus Develops A Centrifugal Flow.

(c) The Rotating Air Is Forced Down Through The Hot Tube And Thus Develops A Pressure Gradient.

(d) Control Valve Is Partly Closed Allowing For The Reversed Axial Flow From Higher Pressure Region.

(e) Closing Of The Control Valve Is Responsible For The Cooling Of The Air Below The Inlet Temperature.

(f) Air Flow In The Forward Direction Gets Heated Up And The Air Flow In The Backward Direction Gets Cooled Up.

Constraints Required For Designing Of The Vortex Tube:

(a) Length Of The Vortex Tube

(b) Vortex Tube Diameter

(c) Type And Number Of Nozzles

(d) Cold End Diameter

Important Points To Remember While Designing A Vortex Tube:

(a) The Length But Within The Limits Should Be Larger Than The Diameter Of The Vortex Tube.

(b) The Lesser The Diameter Of The Tube, The More Would Be The Temperature Separation.

(c) The Nozzle Flow Should Be Tangential Into The Vortex Tube.

(d) The Smaller The Cold Orifice, The Higher Would Be The Yield For The Energy Separation.

(e) Instead Of Placing A Tangential Nozzle In The Cylinder, A Vortex Generator Could Be The Best Alternative.

Description Of The Important Components Of The Vortex Tube:

(a) Vortex Chamber

(b) Hot End Tube

(c) Cold End Tube

(d) Control Valve

Vortex Chamber Is The Place Where A Vortex Flow Is Created When The Inlet Nozzle Is Placed Tangentially. A Hot End Tube Is A Simple Tube With One End Of Which Is Fitted To The Vertex Chamber And Another End Is Fitted To The Control Valve. A Cold End Tube Is A Simple Tube With One End Of Which Is Connected To The Vortex Chamber And Another End Is Set Free. A Control Valve Is A Gate Valve With One End Of Which Is Connected To The Hot Tube. There Are A Number Of Literature

Available On Vortex Tube And All Of Them Tend To Talk About The Design Aspects For The Use Of Machine Cooling Only And Not For Application Of Spot Cooling For Human Comfort. This Research Is Novel Because, It Challenges The Design Of Vortex Tube To Be More Compact And User Friendly For Human Comfort Application. The Object Of This Research Is To Collect All The Information Available In Literature On The Dimensions And Compute A More Efficient And Compact Design For The Use Of Spot Cooling Application For Human Comfort. During The Progress Of This Research It Also Tries To Answer And Present Solution For A Pressing Question For The Need Of Alternative Refrigerants Which Is Sustainable And Eco-Friendly To Be Used In The Industry For The Purpose Of Cooling A Building. That Is Air As A Future Natural Refrigerant.

The Significance Of This Research Work Is So Unique For The Industry Because The Use Of Cfc (Choloro Floro Carbon) And Hfc (Hydro Floro Carbon) Refrigerants Are Harming The Environment And It Is Effecting The Odp (Ozone Depletion Potential) And Gwp (Global Warming Potential), There Are A Need To Have An Eco-Friendly Refrigerant Alternative For Our Cooling Needs, This Research Will Provide The Answer To Have The Use Of Air As A Refrigerant By Designing An Efficient Rhvt Tubes Applicable For Such Application.

Literature Review

In Investigation, The Paper[1],Considered The Energy Separation In A Vortex Tube With A New Screw Type Flow Swirler, Thermocouple Methods And The Effects Of The Inlet Pressure On The Separation. In Conclusion, It Was Observed That Increasing The Inlet Pressure Increases The Flow Temperature And Thus The Separation Process Increases Concluding That The Energy Separation Occurs In A Screw Vortex Generator.

In Investigation, The Paper[2], Dincer Et.Al.(2010) And Attal Ketal(2017) Investigated With The Usage Of The Temperature Vortex Generator, Effects Of The Number Of The Nozzles W.R.T. The Size And The Location. Eiamsa-Ard (2010) Proposed For A Snail Form Of The Design For The Generator.Li Et.Al.(2015) Investigated On The Measurements Of The Temperature W.R.T.The Temperature Distribution. Xue Et.Al. (2012) Investigated On The Measurements Of The Pressure.Rafiee & Sadeghiazad (2020) Investigated On The Effects Of The Velocity Distributions. Polihronov & Straatman (2012) Investigated On The Temperature Drop Which Was Found To Be Adiabatic Expansion Process.

In Conclusion, Various Observation That Were Scientifically Proven Could Speak About The Hidden Mechanism Behind The Functioning Of The Vortex Tube Could Be Explained Properly.

In Investigation, The Paper [3], Focused On The Effects Of Pressure Magnitude, Pressure Drop And Pressure Ratio Between The Inlet And Cold Outlet. Kirmaci Investigated On The Effect Of The Number Of Nozzles As Well As The Effect Of Using Oxygen Gas – Oxygen Gas Achieved Higher Temperature Drop Due To The Increased Exergy Efficiency Of Oxygen. Celik Et.Al.,Kendil & Abdelghany Investigated On The Effects Of The Orifice Diameter. Markal Et.Al. Investigated On The Effects Of The Tip Angle Of The Hot Exit Plug On The Temperature Separation.

In Conclusion, The Process Was Considered As A Polytrophic Process. From Both Of The Observations Above, Aspect Ratio Of 15 Percent Was Preferred. Tip Angle Of 30-Deg Was Preferred.

The Key Considerations During The Design Of Rhvt Tubes As Per The Earlier Research Is Listed Below:

(A) Geometrical Parameters

a. Tube Length: The Length Of The Vortex Tube Has A Significant Impact On Performance. A Tube Of Either Design That Is Efficient Should Be Many Times Longer Than Its

Diameter. The Best L/D Is Determined By Geometrical And Operational Factors. As The Length Of The Vortex Tube Approaches A Critical Length, The Magnitude Of The Energy Separation Increases; However, As The Vortex Tube Length Increases Further, The Magnitude Of The Energy Separation Decreases. L/D Has No Effect On Performance Beyond L/D > 45

b. Tube Diameter: In Experimental Rhvt Studies, Vortex Tube Diameters Ranging From 4.4 Mm To 800 Mm Have Been Used. The Diameters Of The Vortex Tubes Used For Gas Liquefaction And Separation Can Be Much Larger. Vortex Tubes With Smaller Diameters Provide Better Temperature Separation Than Those With Larger Diameters. Due To The Small Diameter Of The Vortex Tube, Kinetic Energy Diffusion Is Low, Resulting In Low Temperature Separation. Lower Overall Tangential Velocities Both In The Core And In The Periphery Region Would Result In Low Diffusion Of Mean Kinetic Energy And Also Low Temperature If The Tube Diameter Was Very Large.

c. Diameter/Area Of Inlet Nozzles: In General, Increasing The Nozzle Diameter Improves Performance. The Ideal Nozzle Diameter Is Around 0.25 Dvt.

d. Type And Number Of Intake Nozzles: The Inlet Nozzles Should Be Designed So That The Flow Enters The Vortex Tube Tangentially For Maximum Temperature Drop. Temperature Separation Increases As The Number Of Inlet Nozzles Increases. To Achieve High Tangential Velocities Near The Orifice, The Inlet Nozzle Should Be Placed As Close To The Orifice As Possible.

e. Cold Orifice: Using A Small Cold Orifice (Dc/D = 0.2, 0.3, And 0.4) Fields Higher Backpressure While A Large Cold Orifice (Dc/D = 0.6, 0.7, 0.8, And 0.9) Allows High Tangential Velocities Into The Cold Tube, Resulting In Lower Thermal/Energy Separation In The Tube. Dimensionless Cold Orifice Diameter Should Be In The Range Of 0.4\Dc/D\0.6 For Optimum Results. When Compared To Other Orifice Configurations Such As Eccentric Orifices, Diaphragm Nozzles, And Diaphragms With Cross Sections Other Than Cylindrical Configurations, Coaxial Orifices Have A Greater Temperature Separation.

f. Hot Flow Control Valve: In The Rhvt, The Hot-End Plug Is Not A Critical Component. The Ideal Angle For The Cone-Shaped Control Valve Is Around 50 Degrees Celsius.

g. Tube Geometry: The Separation Process In Vortex Tubes Used For Gas Separation Is Aided By Tapering The Vortex Tube. There Is An Optimal Conical Angle In Divergent Vortex Tubes, And This Angle Is Very Small. The Rhvt's Performance Is Improved By Rounding Off The Tube Entrance. The System's Performance Is Better With The Muffler Than It Is Without It.

(B) Mass Flows: The Temperature Of The Cold And Hot Fractions Differs Significantly. A Vortex Tube With A Minimum Cold Flow Temperature Design Produces Higher Temperature Drops, Whereas A Vortex Tube With A Maximum Cooling Capacity Design Produces More Cold Fraction And Higher Adiabatic Efficiency. Maximum Effect Of Cooling Is Achieved When A Rhvt Operates At 60% To 70% Cold Fraction. Minimum Cold Temperature Occurs When A Rhvt Operates At 30% Of Cold Fraction.

Important Definitions Considered In This Paper-

1. Temperature Separation: It Is The Difference Between The Hot And Cold Exit Temperatures.

2. Cold Exit Temperature Drop: It Is The Temperature Difference Between The Inlet Stream And The Cold Exit.
3. Tube Aspect Ratio: It Is The Ratio Between The Length And The Diameter Of The Main Hose.
4. The Minimum Temperature Can Be Achieved With An Opening Of 100% Cold End And 0% Hot End Opening.[21]

Objectives & Steps Involved

The Purpose Of This Work Is To Explore The Various Components Requirements From The Various Literatures That Are Available And To Make A Software Model Using Unigraphics. The Steps Of This Research Is Described Below In Fig-2.

And Also To Propose Some Of The Analysis Requirements That Could Be Carried Out To Analyze The Model Parameters In The Future Papers.

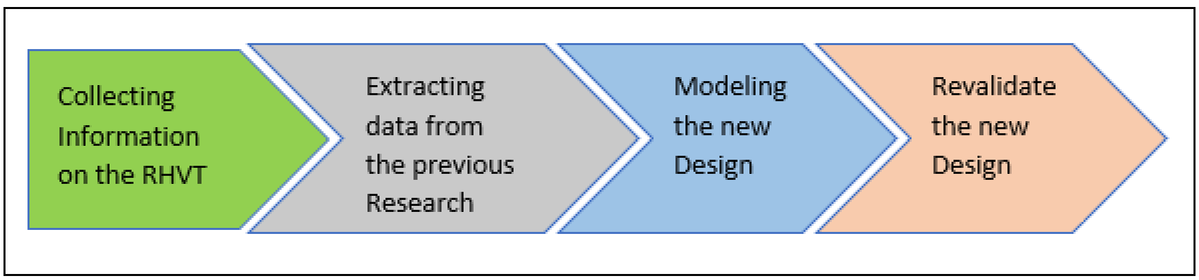

Fig-2 Steps Involved In This Research

To Discuss About The Various Formulae That Are Required To Do The Calculations. And Also To Suggest The Online Calculators Are Essentially Might Be Helpful For Any Of The Future Designers, Analyzers And Manufacturers.

Methodology

The Methodology Of This Work Has Been Divided Into Two Parts. One Part Is To Make A Study On The Existing Designs From The Literature Reviews And Second Part Is To Frame The Design Specifications For The New Design From The Simplified, Specified, Standardized And Diversified Observations And Transform It In A Working Model.

Existing Designs From The Literature Reviews:

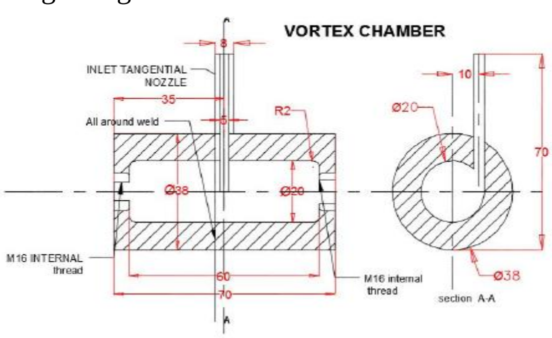

Fig-3.A Vortex Chamber Design[1]

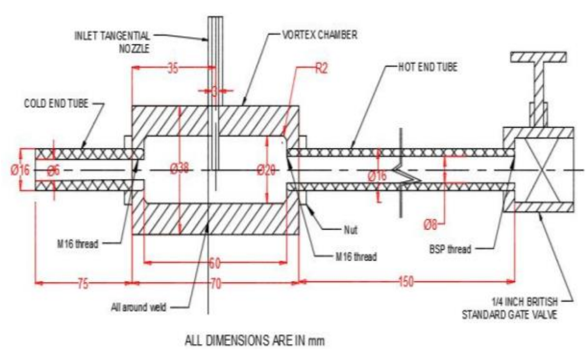

Fig-3.B Complete Vortex Tube Schematic[1]

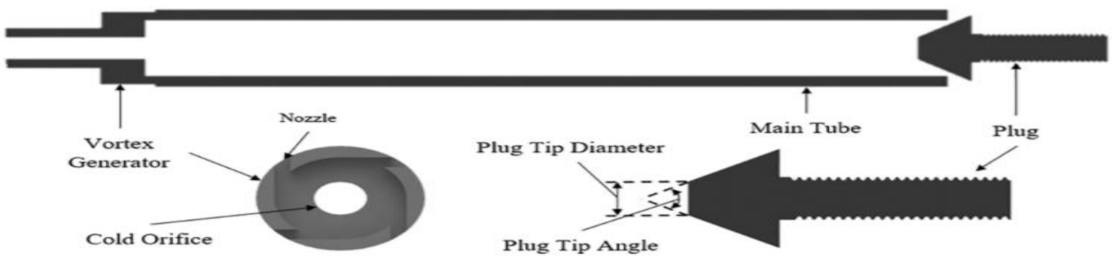

Fig-4 Sample Design From The Literature Survey

Proposed Designs For The New Model

In The Proposed Design, The Parts That Are Required To Be Included Are Cold End Tube, Inlet Tangential Nozzle, Vortex Chamber, Hot End Tube, British Standard Gate Valve, M16 Thread And Nuts.

Data-Collection And Data-Interpretation

Available Results

Below Are Some Results From The Researches Summarized In Table-1

Table-1: Experimental Results Conducted By Other Researchers.

Sno	Reference	Inlet Pressure (Bar)	Length Of Vt (Mm)	Vt Dia (Mm)	Vt Inlet Dia (Mm)	Cold Mass Flow Fraction	Drop In Cold Outlet Temp K	Raise In Hot Outlet Temp K
1.	Hilsch[23]	7.1	230	4.6	1.1	0.23	45	13
2.	Scheper[24]	2.02	914	38.1	6.35	0.26	11.7	3.9
3.	Scheller & Brown[25]	6.18	1092	25.4	-	0.506	23	15.6
4.	Stephan Et Al[26]	6.08	352	17.6	4.1	0.3	38	18
5.	Promovonge & Eiamsa-Ard [27]	4.56	720	16	2.0	0.38	18	8
6.	Hamoudi Et Al[28]	5.07	100	2	0.8	0.57	18.5	11
7.	Eiamsa-Ard Et Al [29]	4.05	720	16	2.0	0.3	17	4
8.	Im & Yu [30]	2.02	280	20	8.1	0.5	17	12

9.	K Kiran Kumar [31]	4.0	175	13	8	0.23	12	25

The Design Details Of This Research Has Been Considered As Mentioned Below:

i. Height Of Inlet: 27mm
ii. Inlet Nozzle Inner Diameter (Mm)= 15.8 Mm
iii. Intlet Nozzle Outer Diameter (Mm)= 21.36 Mm
iv. Vortex Chamber Inner Diameter (Mm)= 45.85 Mm
v. Vortex Chamber Outer Diameter (Mm)= 54 Mm
vi. Length Of Vortex Chamber : 57mm
vii. Hot End Tube Inner Diameter (Mm)= 19 Mm
viii. Hot End Tube Outer Diameter (Mm)= 25.45 Mm
ix. Hot End Tube Length (Mm)= 174.5 Mm
x. Cold End Tube Inner Diameter (Mm)= Beginning 9.5 Mm And At The End: 14.99 Mm (Conical)
xi. Cold End Tube Outer Diameter (Mm)= At The End : 19.40 Mm
xii. Cold End Tube Length (Mm)= It Is Vortex White Plastic Tube (47mm Length)
xiii. Total Length Of The Tube: 282.70 Mm (With Out The Hot End Cap)
xiv. Hot End Cap Inner Dia: 12.5 Mm
xv. Hot End Outer Dia: 17.30 Mm
xvi. Length Of Hot End Cap: 38.25 Mm
xvii. Threaded Portion Of Hot End Cap: 17mm
xviii. With One Neoprene O Ring Washer
xix. 4 Slots In Hot End Cap: 6 Mm Each

Data-Analysis And Data-Validation

(A) The Data-Analysis Could Be Carried-Out With The Below Mentioned:

Units Of Specific Heat Of Air (Cp) In Kj/Kgk ; Mass Flow Rate (M) In Kg/Sec; Temperature(T) In °C ;Temperature Difference(.T) In°C ;Static Temperature Drop(Tc) In °C ;Relative Temperature Drop (.Trel) In°C ;Cold Mass Fraction (µ) -Constant; Cooling Or Heating Rate (Q) In Kj/Sec; Velocity (V) In M/Sec; Actual Work Was Done By The Compressor (W) In Kw; Adiabatic Efficiency Of Vortex Tube (.Ad) In %.

(B) The Important Formulae To Be Considered For The Performance Of The Vortex Tube Are As Mentioned Below [21]:

Temperature Drop At The Cold End Is The Temperature Difference Between The Inlet Temperature And Cold End Temperature-.Tc = (Ti -Tc) Where Ti Is The Inlet Temperature And Tc Is The Cold End Temperature Drop At The Hot End Is The Temperature Difference Between Hot End Temperature And Inlet Temperature Where This The Temperature At Hot End And Ti Is The Inlet Temperature Th = (Th - Ti);The Cooling Effect Is The Amount Of Cooling Encountered At Particular Instance Which Is Denoted By Qc,Qc= Mc Cp (Ti-Tc);The Heating Effect Is The Amount Of Heating Encountered At The Hot End At A Particular Instance Which Is Denoted By Qh,Qh= Mh Cp (Th-Ti);Actual Work Done By The Compressor Can Be Estimated By The Following Relation, W = (N/N-1) X P1v1 X [(P2/P1) (N-1/N) -1],Where P1 Is The Atmospheric Pressure Inlet To The Compressor And P2 Is The Outlet Gauge Pressure. The Coefficient Of Performance Is The Ratio Of Cooling Effect To Actual Work Done By The Compressor, Cop =Qc/W.

(C) The Data-Validation Could Be Carried-Out With The Below Mentioned:

Https://Www.Trelleborg.Com/En/Seals/Resources/Design-Support-And-Engineering-Tools/Fluid-Mechanics-Calculator

Https://Www.Ajdesigner.Com/Index_Fluid_Mechanics.Php

Https://Www.Engineeringtoolbox.Com/Fluid-Mechanics-T_21.Html

Http://Educypedia.Karadimov.Info/Education/Mechanicsjava.Htm
Https://Www.Engineersedge.Com/Calculators.Htm

Results

The Results Obtained For The Above Are As Mentioned Below From Fig.-5 To Fig-27.

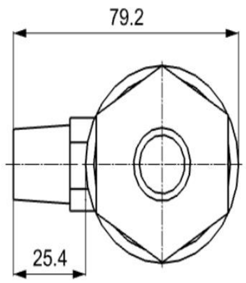

Fig-5 Cold End Side View, Where The Cold Air Comes Out And The Intake Section

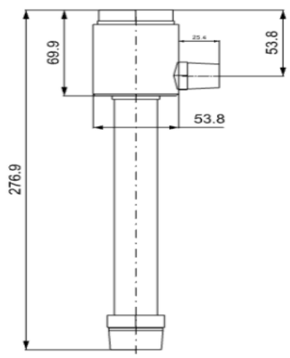

Fig-6 Tube Details And Measurements

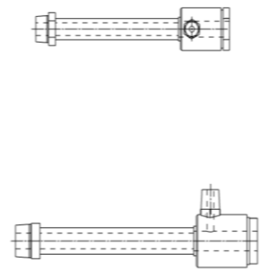

Fig-7 Views On Front And Top Side

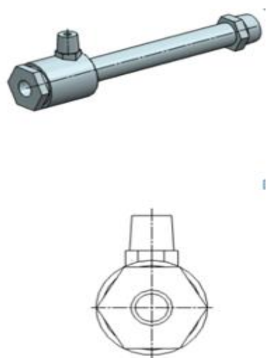

Fig-8 Isometric View Of The Tube With Col Air Exit And Entry Section

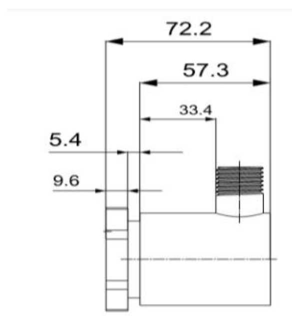

Fig-9 Input Section, Which Acts As Compressed Air Entry Into The Rhvt Tube

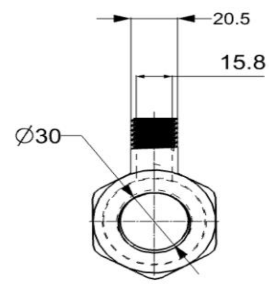

Fig-10 Hot End Side View, Where The Hold End Leaves The Rhvt Out Of The Tube

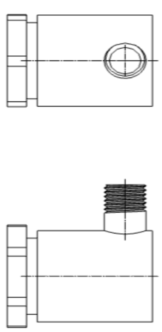

Fig-11 Input Section, Which Acts As An Intake For The Rhvt Side View And Top View

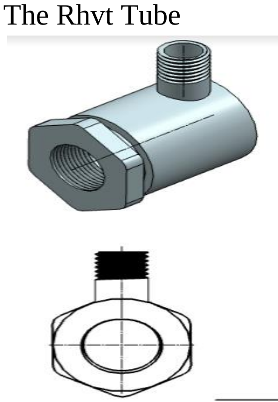

Fig-12 Isometric View Of The Input Section From The Top And Put Air Exit Is Seen

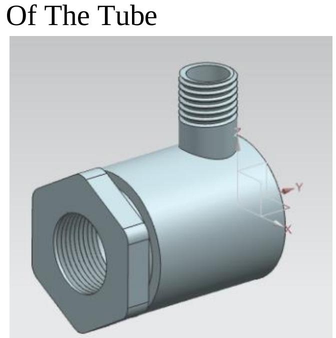

Fig-13 Another View Of Input Section With Cold Air Outlet

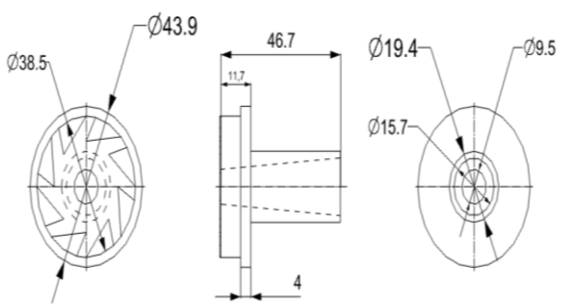

Fig-14 Turbulator Front View, Side View And End View

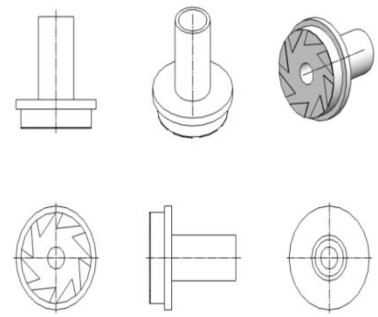

Fig-15 Some More Views Of Turbulator

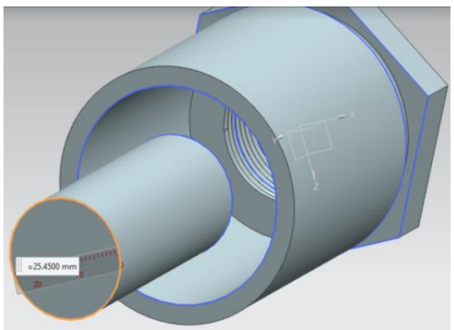

Fig-16 Cold End Detailed View

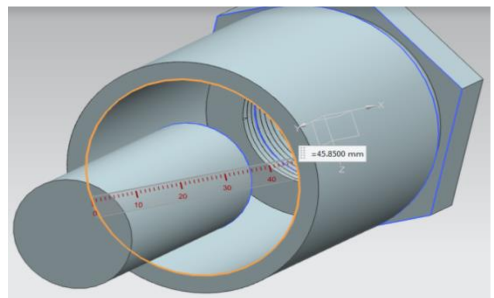

Fig-17 Length Of Cold End View

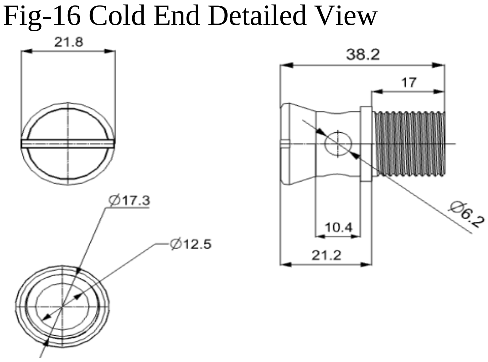

Fig-18 Hot End Cap Details

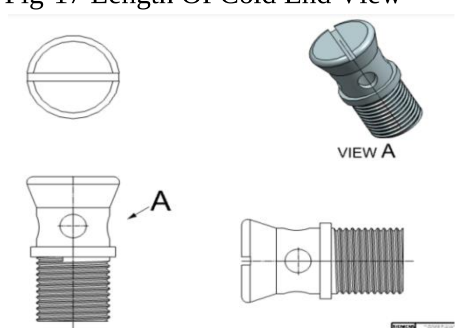

Fig-19 Hot End Cap With Threads

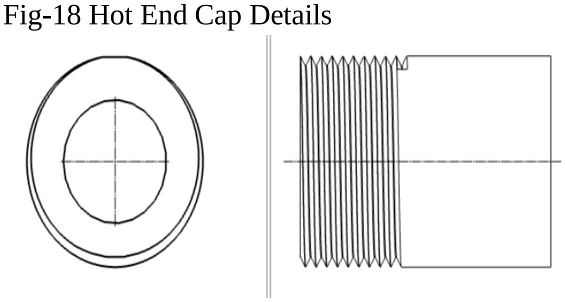

Fig-20 End Screw Cap Top And Side View

Fig-21 Isometric Screw End Cap With Slot Hole To Regulate The Exit Hot Air.

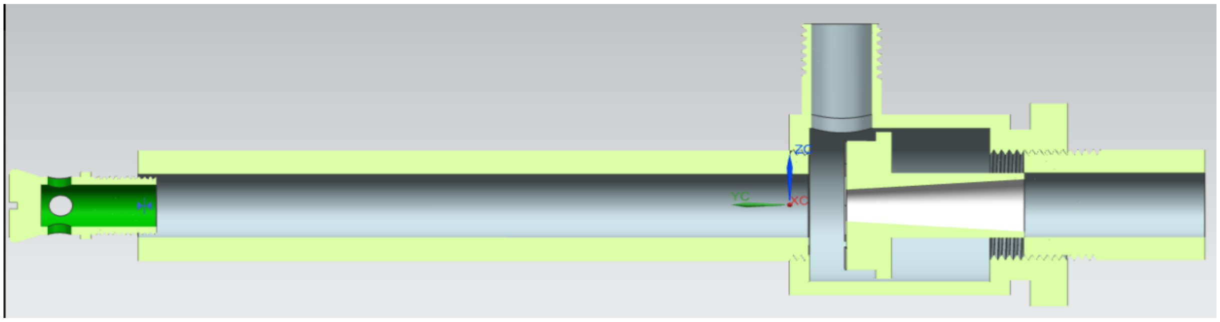

Fig-22 A Complete Sectional View Of The Rhvt Tube Showing The Air Inlet, Air Out Let And Turbulator Is Seen In An Assembled Section.

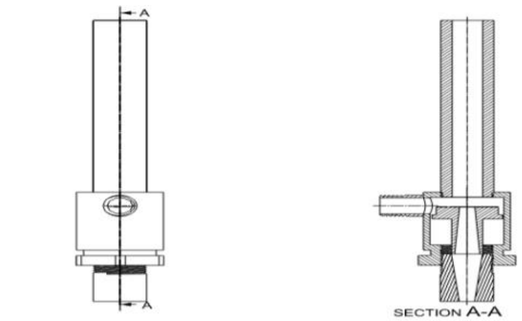

Fig-23 A Top View Of The Rhvt Tube

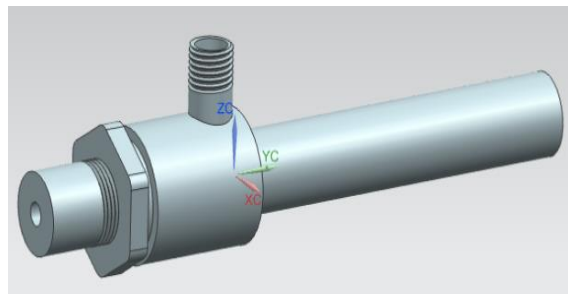

Fig-24 An Isometric View Of The Rhvt Tube

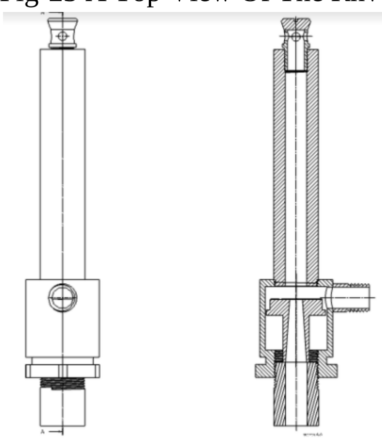

Fig-25 Assembled View Of The Tube

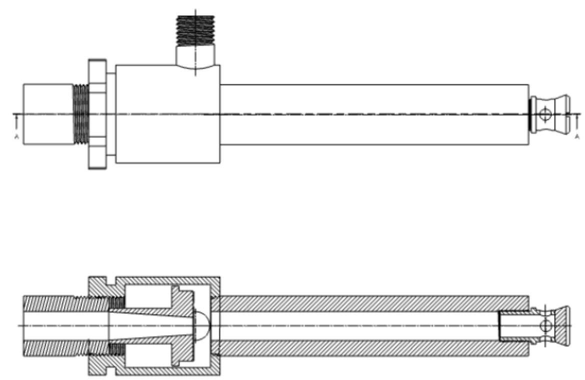

Fig-26 Top View Of The Tube With Sections Showing The Turbulator Section

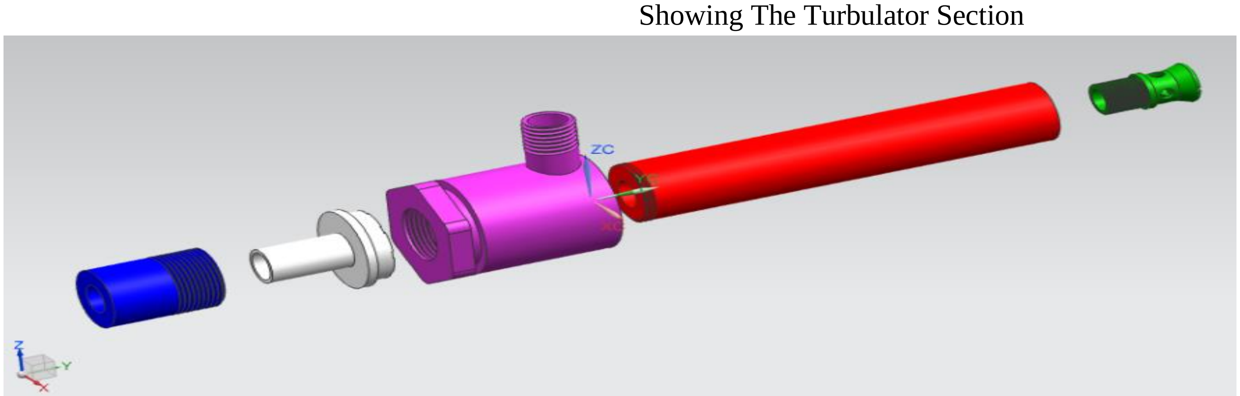

Fig-27: Exploded View Of The Vortex Tube

Conclusion And Discussion

The Final Product Design Is Hence Made Ready For The Vortex Tube With All The Required Bill Of Materials As Shown Above. The Design Is Revalidated From The Previously Work Done In Table-1, The Diameter And Length Of The Newly Designed Tubes Are Very Close And In Tolerated Vales. Next Step Is To Analyze This Design Using Ansys By Applying The Inlet And Exit Parameters And Check The Results For Fine Tuning.

Now Since The Design Part Is Ready, The Parameters For The Purpose Of The Analysis Could Be Easily Calculated Namely, Inlet Velocity (V_i) In M/S, Inlet Area($A_i=\frac{\pi}{4}D^2$) In Sqm,

Discharge At Inlet ($Q_i=A_i*V_i$) In Cum/S,

Density At Inlet (ρ_I=P/Rt) In Kg/Cum,

Mass Flow Rate At Inlet ($M_i= Q_i * \rho_I$) In Kg/S,

Mass Flow Rate At Cold End(M_c) In Kg/S For Various Kinds Of The Materials Namely, Stainless Steel, Brass, Copper And Upvc.

Future Work

1. To Analyze The Complete Product Using An Ansys Software By Applying The Parameters.
2. To Calculate The Below Mentioned For The Prototype Produced.

Cold End Velocity (V_c)M/S ,

Area Of The Cold End ($A_c=\frac{\pi}{4}D^2$) Sqm,

Density Of Cold Air (ρ_C) Kg/Cum,

Discharge At The Cold End (Q_c) Cum/S ,

Mass Flow Rate Of The Cold End (M_c)Kg/S And

Cold Flow Mass Ratio =Mass Flow Rate At Cold End / Mass Flow Rate At Inlet (M_c/ M_i)

3. The Future Work Would Be To Plan-Design-Develop-Manage Risks-Test-Produce-Release-Support By Manufacturing A Prototype And Do A Field/Factory Setting For This Product.

References

[1] Vitovsky, O. V. "Experimental Study Of Energy Separation In A Ranque-Hilsch Tube With A Screw Vortex Generator." International Journal Of Refrigeration 126 (2021): 272-279.

[2] Parker, Mark J., And Anthony G. Straatman. "Experimental Study On The Impact Of Pressure Ratio On Temperature Drop In A Ranque-Hilsch Vortex Tube." Applied Thermal Engineering 189 (2021): 116653.

[3] Dincer K Et.Al. Experimental Investigation Of Performance Of Hot Cascade Type Ranque-Hilsch Vortex Tube And Exergy Analysis, International Journal Of Refrigeration, 28, 442-450 (2011).

[4] A Maheshwaran, Et. Al. Design Of Vortex Tube And Analysis Of Its Flow Characteristics, International Journal Of Engineering And Techniques,Vol-4,Iss-5,45-51(2018)

[5] G L Ranque, Method And Apparatus For Obtaining From A Fluid Under Pressure Two Currents Of Fluids At Different Temperatures, U S Patent No. 1952281,1934.

[6] R Shamsoddini, A H Nezhad, "Numerical Analysis Of The Effects Of Nozzles Number On The Flow And Power Of Cooling Of A Vortex Tube " International Journal Of Refrigeration , Vol 33 Pp774-782,2010.

[7] Ratnesh Sahu, Rohit Bhadoria And Deepak Patel,” Performance Analysis Of A Vortex Tube By Using Compressed Air”,International Journal Of Scientific & Engineering Research Volume 3, Issue 9, September-2012
[8] Design & Analysis Vortex Tube Refrigeration System 353 Www.Tjprc.Org Scopus Indexed Journal Editor@Tjprc.Org

[9] Akash S. Bidwaik And Sumit Mukund Dhavale, “To Study The Effects Of Design Parameters On Vortex Tube With Cfd Analysis”, International Journal Of Engineering Research & Technology (Ijert) Issn: 2278-0181, Vol. 4 Issue 10, October-2015.

[10] Jaykumar D. Golhar And B. R. Rathod “Experimental Investigation And Optimization Of Vortex Tube With Regard To Nozzle Diameter”, International Conference On Benchmarks In Engineering Science And Technology Icbest 2012 Proceedings Published By International Journal Of Computer Applications, 2012.
[11] T Dutta, K P Sinha,Mahapatra, S S Bandyopadhyay, Comparison Of Different Turbulence Modelsin Predicting The Temperature Separation In A Ranque Hilsch Vortex Tube, International Journal Of Refrigeration, Vol 33, Pp 783-792,2010.
[12] M. Dalavi, Mahesh Jadhav, Yasin Shaikh, Avinash Patil, “Modeling, Optimization & Manufacturing Of Vortex Tube And Application”, Iosr Journal Of Mechanical And Civil Engineering (Iosr-Jmce), Pp: 45–49
[13] M Baghdad, A Ouadha,O Imine,Y Addas, Numerical Study Of Energy Separation In A Vortex Tube With Different Rans Models, International Journal Of Thermal Science, 50,2011, 2377-2385.
[14] Kiran D. Devade And Ashok Pise “Parametric Review Of Ranque-Hisch Vortex Tube”, Columbia International Publishing American Journal Of Heat And Mass Transfer (2017) Vol. 4 No. 3 Pp. 115–145.

[15] Smith Eiamsa-Ard And Pongjet Promvonge" Review Of Ranque–Hilsch Effects In Vortex Tubes”, Renewable And Sustainable Energy Reviews12 (2008) 1822–1842.

[16] Mahmood Farzaneh-Gord And Meisam Sadi,” Improving Vortex Tube Performance Based On Vortex Generator Design”, The Faculty Of Mechanical Engineering, Shahrood University Of Technology, Shahrood, Iran.

[17] Kiran Devade, Ashok Pise, “Effect Of Cold Orifice Diameter And Geometry Of Hot End Valves On The Performance Of Converging Type Ranque Hilsch Vortex Tube", Energy Procedia, 54 ,2014, Pp 642–653

[18] R G Deissler, M Perlmutter, Analysis Of The Flow And Energy Separation In A Vortex Tube, Internationaljournal Of Heat And Mass Transfer1 (1960) 173-191

[19] Ahlborn Bk,Gordon, Jm 2000, “The Vortex Tube As A Classical Thermodynamic Refrigeratrion Cycle”, J Applied Physics, Vol 23, No.15, Pp 1971-1980.

[20] M. H. Saidi, M. S. Valipour, “Experimental Modeling Of Vortex Tube Refrigerator”, Applied Thermal Engineering, 23, 2003, Pp 1971–1980.

[21] Jitendra Patil Et Al” Performance Analysis Of Vortex Tube Refrigeration System”,International Journal Of Advance Research, Ideas And Innovations In Technology,Vol 5, Iss2,705-710.

[22] Kiran Devade, Ashok Pise, "Effect Of Cold Orifice Diameter And Geometry Of Hot End Valves On The Performance Of Converging Type Ranque Hilsch Vortex Tube", Energy Procedia, 54, 2014, Pg No 642-653.

[23] Hilsch, Rudolf. "The Use Of The Expansion Of Gases In A Centrifugal Field As Cooling Process." Review Of Scientific Instruments 18.2 (1947): 108-113.

[24] Scheper Gw (1951) The Vortex Tube–Internal Flow Data And A Heat Transfer Theory. J. Asre Refrigeration Eng 59:985–989

[25] Scheller Wa, Brown Gm (1957) The Ranque-Hilsch Vortex Tube. Ind Eng Chem 49(6):1013–1016.

[26] Stephan K, Lin S, Durst M, Huang F, Seher D (1983) An Investigation Of Energy Separation In A Vortex Tube. Int. J. Heatmass Transf 26:341–348.

[27] Promvonge P, Eiamsa-Ard S (2005) Investigation On The Vortex Thermal Separation In A Vortex Tube Refrigerator. Sci Asia 31: 215–223

[28] Hamoudi Af (2006) An Investigation Of Micro-Scale Ranque-Hilsch Vortex Tube Master's Thesis. Dissertation, University Of Windsor

[29] Eiamsa-Ard S, Wongcharee K, Promvonge P (2010) Experimental Investigation On Energy Separation In A Counter-Flow Ranque–Hilsch Vortex Tube: Effect Of Cooling A Hot Tube. Int Commun Heat Mass Transf 37:156–162.

[30] Im Sy, Yu Ss (2012) Effects Of Geometric Parameters On The Separated Air Flow Temperature Of A Vortex Tube For Design Optimization. Energy 37:154–160.

[31] K. Kiran Kumar Rao, Dr. A. Ramesh, M. Rajesh, Dr.G.Naga Malleswara Rao (2016), Performance Of Vortex Tube With Comparing By Cfd Ananlysis, Ijre, Vol. 03 No. 06, June 2016, Issn 2348-7852.