IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684, p-ISSN: 2320-334X
PP 06-12
www.iosrjournals.org

Optimizing the Parameter of The Vortex Tube Through CFD Analysis For Sustainable Manufacturing

K.K.Arun[1] S.Tamil selvan[2]
Asst Professor, Department Of Mechanical Engineering, Kumaraguru College of Technology
Coimbatore. Tamilnadu, India
PG Student, Department Of Mechanical Engineering, Kumaraguru College of Technology
Coimbatore. Tamilnadu, India
tamilau08@gmail.com

Abstract— *Sustainable is the future which develops new techniques which reduce the environmental impact of manufacturing. Sustainability is more important in today's society due to the increasing demand for a more eco-friendly population. Vortex tube is a sustainable tool used for spot cooling, which does not require any refrigerant and electricity. Vortex tubes are maintenance free which does not require any maintenance. This work will optimize the parameter of the tube for increasing the cooling temperature. Different vortex tube with varying length by CFD analysis. The optimum cold end diameter (dc) and the length to diameter (L/D) ratios and optimum parameters for obtaining the minimum cold gas temperature are obtained through CFD analysis. The importance for this work is to show the vortex tube is alternative and sustainable tool for spot cooling in machining operation by analysing the performance of vortex tube with different profile, length and diameter ratio of vortex tube and cold orifice diameter and hot outlet area using CFD tool.*

Keywords: *—Sustainability; Vortex tube, Energy separation, CFD module, modified design.*

I. INTRODUCTION

The research presented in this paper developing a suitable alternative sustainable tool for cooling cutting edge in metal cutting process. Sustainability requires the reconciliation of environmental, social equity and economic demands it all so referred to as three pillars of sustainability, sustainable manufacturing is defined as the creation of manufactured products that use the processes that are non polluting, conserve energy and natural resources and are economically sound and safe for employees, along with competitiveness, profitability and productivity environmental stewardship and sustainability are likely to prove increasingly important for manufacturing in the future.

Fig 1: EXAIR Mediem type vortex tube with 15 SCFM vortex generator

Vortex tube is a sustainable tool used for spot cooling application. it was invented by a French physicist named ranque in 1933 and it was improved by germen engineer Rudolf hilsch in 1947. Vortex tube is simple device having no moving part. in the vortex tube high pressure air split into hot air and cold air. The vortex tube consist of a inlets, vortex chamber, inlet nozzles and main tube, control valve, orifice, the high pressure air passes through tangential nozzles, when the air passes through tangential nozzle gas expands and attain high angular velocity and making the turbulence flow. Vortex tube having two exit point one is hot end another one is a cold end cold end having divergent outlet. The hot end having the

Parameters	**values**
Tube inner diameter, D	10.20mm
Cold orifice diameter d_c	4.56mm
Tube length/diameter	11.37
Number of nozzle	6
Tangential inlet nozzle width	1.41mm
Vortex inlet height	0.97mm
Hot exit gap	0.3mm

Table:1 Vortex tube Dimension

Control valve. The mass flow rate controlled by control valve at hot outlet. The energy separation phenomenon in the vortex tube is quite complex to understand. The energy separation effect is connected with a energy interaction between the two layer that form inside the vortex tube, swirling flow and larger angular velocity leads to the greater and better energy separation effect. Eiamsa-ard [1] suggest that for maximum cooling temperature cold mass friction (μ_c) should be 30% to 40%.but till now The energy separation in the vortex tube is not fully understood. Aljuwayhel et al[2] recirculation nature and high velocity swirling flow is challenge to the traditional and non-invasive flow visualization techniques .Liew et al [3] revealing the relation the RHVT and Maxwell's demon. Yunpenq xuy et al [4] the temperature drop at cold end is because of pressure gradient in the front vortex tube and the temperature rice at the hot end is the multi circulation flow structure in the outer part of the main tube.

II. VORTEX TUBE GEOMETRY

This vortex tube consist of circular tube and vortex chamber and vortex generator and stopper and hot end control valve and 6 tangentical inlet is used.hot end control valve used to adjest the mass flow in the cold end.the gementrical parameter of vortex tube like length and diameter ratio and orifice diameter and hot end control valve gap are analysed.

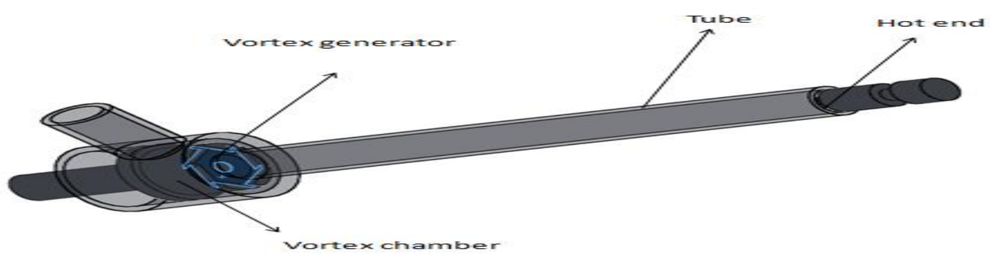


Fig: 2 Vortex tube model

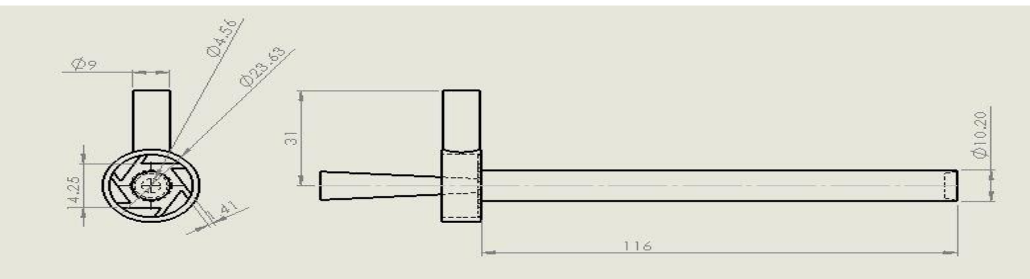


Fig 3: vortex tube fluid path geometry

The different length working tube is used in the CFD analysis. The diameter of the main tube is 10.20mm. nader pourmahmoud et al [5] investigated the L/D ratio and 9.3 is optimum ratio for energy separation. The 6 tangential nozzles is designed for creating the high turbulence flow width of the nozzle is 1.41mm and height of the slot is 0.97mm length of the nozzle is 2.9mm and cold orifice diameter is 4.56mm. L/D radio14.21, 12.35 11.37, 10.39, 9.31, 8.33, 7.35, 6.37, 5.39 is taken for analysis. L/D radio 5.39 giving the best energy separation in our case 6 tangential inlet nozzle is used in this CFD model. And different D/d ratio 1.99, 1.64, 2.31, 2.04, 3.4 are analyzed and 1.64 is giving the optimum result.

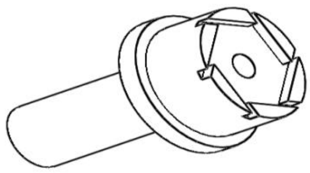


Fig 4: vortex generator

III. CFD MODEL

The ansys icem CFD is used for making the volume mesh for the vortex tube model. the standard k-epsilon turbulence model is used. Skye et al [6] investigate the RNG k-epsilon turbulence model but the result is not correlated with the experimental data, Reynolds stress equation also can't be converge for this simulation walls are consider as no slip boundary condition. the 3D model is meshed with tria element in icem meshing tool, the velocity along the axial direction is the reason for creating the forced and free vortex zone inside the tube.

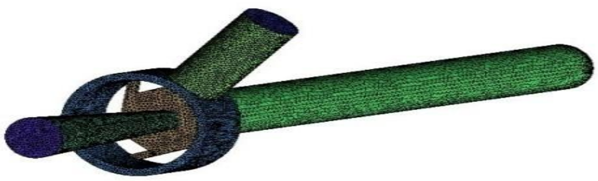


Fig 5: Tetra mesh

The present work is done using ansys fluent 14.5; it is the volume based solver. The solver used 3 dimensional steady, compressible, pressure based setup, density based solver diverged for this vortex tube problem, energy equation is on for capture the energy and temperature distribution. K-epsilon model is used 2equation model is used and for finding the wall friction on fluid standard wall function is used. Finding the heat dissipation between the layers can be captured by viscous heating function. Air is used as material body. Because the flow is considered as compressible flow ideal gas equation is used. No interaction between environment and computation domain.The inlet of the vortex tube is defined as a pressure inlet and cold outlet and hot outlet is defined as a pressure outlet and the atmospheric temperature is given as a input in the model. Wall is assumed as a adiabatic condition. The fluent package solved by mass, momentum and energy equation.

Mass balance equation

$$\frac{\partial x}{\partial t} + \nabla\cdot(\rho u)=0 \qquad (1)$$

Momentum balance equation

$$\frac{\partial(\rho u)}{\partial t} + \nabla\cdot(\rho uu)=-\nabla p+\mu \nabla^2 u \qquad (2)$$

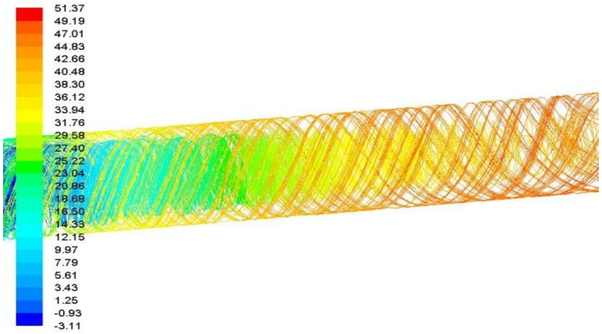
Energy balance equation

$$\rho C_P \left[\frac{\partial T}{\partial t} + \nabla \cdot T(u)\right] = k \nabla^2 T \qquad (3)$$

Ideal gas equation

$$\frac{p}{\rho} = RT \qquad (4)$$

The inlet pressure and inlet ambient temperature is giving as a input, inlet pressure is 5.5 bar and inlet ambient temperature is 27°c.cold outlet pressure is set as environmental pressure and hot outlet is also a environmental pressure. Maurya et al[7] Energy separation in the vortex tube is due to the double swirling flow structure . The back flow because of the pressure variation in the swirling region and hot outlet region and the cold outlet region, the negative pressure created inside the cold end important for back flow.



Total temperature in °c

Fig: 6 Energy separation in the vortex tube L/D=5.39

Separation of two layers clearly show the energy transfer between the two layers and the inner layer give it heat energy in the form of kinetic energy.

IV. MODIFICATION IN DESIGN

Fig 7: convergent vortex inlet

For L/D ratio 5.39 and 2.22mm orifice radios convergent type vortex inlet is used but it will not give the better cold end temperature. Convergent nozzle reduces the inlet velocity because of the wall friction.

V. RESULT

L/D RATIO	COLD END TEMBERATURE IN°C
5.39	2.34
6.37	2.85
7.35	3.37
8.33	3.42
9.31	4.93
10.39	5.64
11.37	3.54
12.35	7.29
14.21	6.86

Table 2: L/D ratio and cold end temperature

Total Temperature path line °c for L/D=5.39

Fig8: cold and hot side energy separation path line

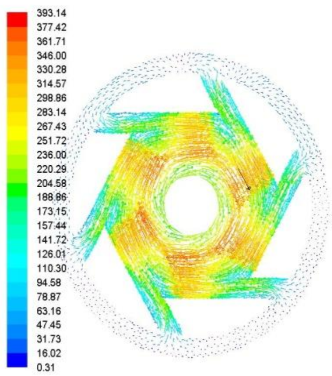


Fig 9: vortex inlet velocity vector of L/D=5.39

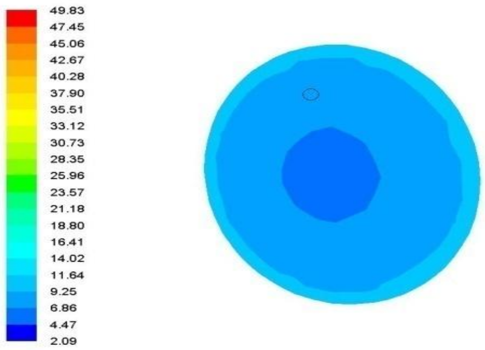


Fig: 11 L/D 14.5 hot out temperature contours in°c

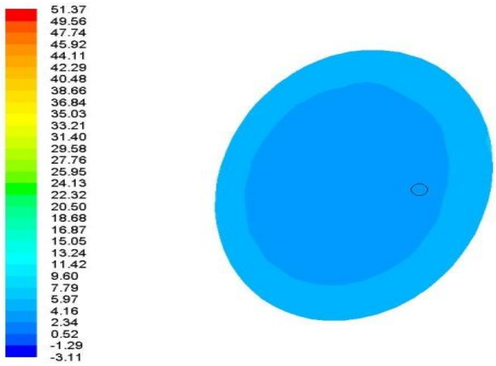


Fig: 12 L/D 5.39 Cold end temperature contours in°c

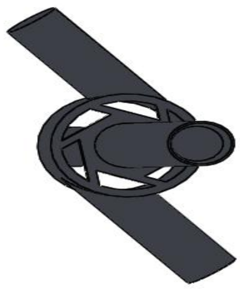


Fig 13: vortex tube with two inlets

When two inlet nozzle and hot end gap is 0.4mm for L/D ratio 5.39 and orifice diameter R=2.22 give optimum cold end temperature 1.31°c.

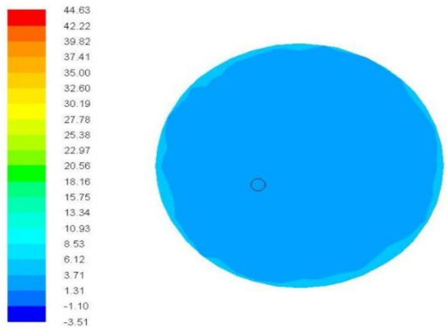


Fig: 14 L/D 5.39 cold end temperature contours in °c for two nozzle inlet.

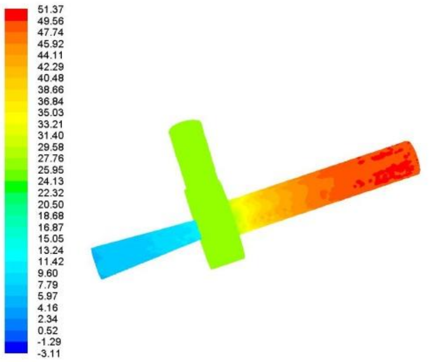


Fig 13: Temperature Contours in°c

VI. CONCLUSION

Numerical investigation of L/D 19.7, 14.5, 11.76, 11.37, 10.39, 9.31, 8.33, 7.35, 6.37, 5.39 is analyzed, 5.39 is found as a optimum ratio for the vortex tube and based on the above result. The hot end temperature as 48°c and cold end temperature as 2.37°c.Then by reducing cold orifice radius R=2.56 to R=2.2 then cold end temperature reduced to 1.60°c.Hot end gap 0.4mm with two inlet nozzles give cold end temperature 1.31°c.

REFERENCES

[1] “Experimental investigation of energy separation in a counter flow Ranque Hilsch vortex tube with multiple inlet snail entries ,” Int. Commun. Heat Mass Transf., vol. 37, no. 6, pp. 637–643, 2010.

[2] N. F. Aljuwayhel, G. F. Nellis, and S. A. Klein, “Parametric and internal study of the vortex tube using a CFD model ” vol. 28, pp. 442–450, 2005.

[3] R. Liew, J. C. H. Zeegers, J. G. M. Kuerten, and W. R. Michalek, “Maxwell ’ s Demon in the Ranque-Hilsch Vortex Tube,” vol. 054503, no. August, pp. 3–6, 2012.

[4] Y. Xue, M. Arjomandi, and R. Kelso, “The working principle of a vortex tube Tube vortex□ : principe de fonctionnement,” Int. J. Refrig., vol. 36, no. 6, pp. 1730–1740, 2013.

[5] N. Pourmahmoud and A. R. Bramo, “THE EFFECT OF L / D RATIO ON THE TEMPERATURE SEPARATION,” vol. 6, no. January, pp. 60–68, 2011.

[6] H. M. Skye, G. F. Nellis, and S. a. Klein, “Comparison of CFD analysis to empirical data in a commercial vortex tube,” Int. J. Refrig., vol. 29, no. 1, pp. 71–80, Jan. 2006.

[7] R. S. Maurya and K. Y. Bhavsar, “Energy and Flow Separation in the Vortex Tube□ : A Numerical Investigation,” pp. 25–32, 2013.