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Experimental Investigation for Optimizing Parameter of Vortex Tube for Sustainable Heating System

[1] R. Dhineshkumar,
PG student, Thermal Engineering,
Mechanical Department, CMS College of Engineering ,
Namakkal, Tamil Nadu, India.

[2] D. Ashokumar, M.Tech,
Assistant Professor, Mechanical Department,
CMS College of Engineering, Namakkal,
Tamil Nadu, India.

***Abstract*:- Sustainability developed in many countries; it is mainly implemented in engineering design, manufacturing and supply chain management field. Sustainable is defined as meeting the needs of the present generation by not taking the need of the feature generation. Sustainability is more important in today's culture due to the increasing demand for a more eco-friendly society and a growing population. Sustainability is the reconciliation of environmental, society and economic. Vortex tube is used as sustainable tool for manufacturing system. Vortex tubes having no moving part so there is no need for maintenance. This work is numerical analysis on optimizing the parameter of the vortex tube for minimizing the temperature at cold end. The length and diameter of the vortex tube are optimized, cold end orifice radios and hot end gap are optimized using numerical tool. The inlet profile of the vortex tube also modified and analyzed. The importance of this work is reducing the cold end temperature of the vortex tube. By reducing the cold end temperature we can use the vortex tube in machining operation alternative for the flood cooling method.**

INTRODUCTION

INTRODUCTION TO SUSTINABILITY

The term gained widespread usage after 1987, when the Brundtland Report from the United Nations World Commission on Environment and Development defined sustainable development as development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs.

Sustainability has been applied to many fields, including engineering, manufacturing and design. Manufacturers are becoming increasingly concerned about the issue of sustainability. Recognition of the relationship between manufacturing operations and the natural environment has become an important factor in the decision making among industrial societies.

Sustainability requires the reconciliation of environmental, social equity and economic demands It is also referred to as the three pillars of sustainability Sustainable manufacturing is defined as the creation of manufactured products that use processes that are nonpolluting, conserve energy and natural resources, and are economically sound and safe for employees, communities, and consumers.

Sustainability is the driver for innovation; innovation promotes accelerated growth in manufacturing. Manufacturing is the engine for wealth generation and societal wellbeing and economic growth heavily depend on the level and quality of education and training. Sustainable manufacturing Innovations elements are Remanufacture Redesign, Recover, Recycle, Reuse, Reduce. Modern manufacturers recognize the need to use resources efficiently. This extends right through the production process where they need to be very cognizant of the resources they use, by-products created and ultimately waste that cannot be used. You will find that manufacturers are very careful to use the minimum of resources, transform or modify those resources as efficiently as possible and when the process is completed, create as least waste and by products as possible. Along with competitiveness, profitability and productivity, environmental stewardship and sustainability are likely to prove increasingly important for manufacturing in the future and in setting the main priorities for advancing manufacturing operations and technologies.

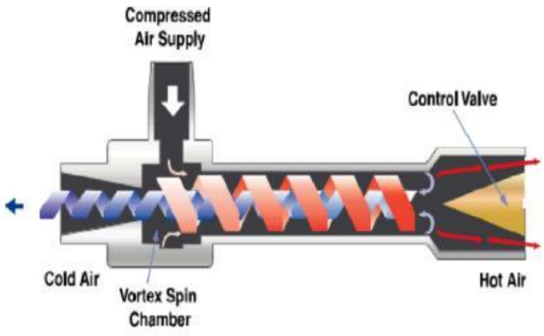
INTRODUCTION TO VORTEX TUBE

Exair 3205 Vortex Tube

The vortex tube was invented by a French physicist named Georges J. Ranque in 1931 when he was studying processes in a dust separated cyclone. It was highly unpopular during its conception because of its apparent inefficiency. The patent and idea was abandoned for several years until 1947, when a German engineer Rudolf Hilsch modified the design of the tube .Since then, many researchers have tried to find ways to optimize its efficiency. Until today, there is no single theory that explains the radial temperature separation.

The idea behind a vortex tube has been alluded to as early as eighteenth century. James clerk Maxwell, a Scottish physicist and mathematician famous for his electromagnetic field, theories about the dynamics of molecular movement, where in the hot and cold air molecules are separated inside a device by the aid of a certain force. Unable to identify this force, he settled for a “friendly little demon”, responsible for separating hot and cold particles.

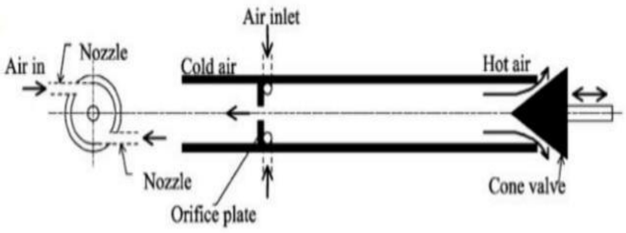
But the discovery of the vortex Tube is mainly attributed to French physicist, George J. Ranque. He is responsible for the initial structure and design of the vortex tube, he use of gas as the first medium in testing this strange heating-cooling device. The man, however, failed, and Maxwell Demon did not see the light of day until 1945, when Rudolph Hilsch, a physicist from Germany, produced a scientific treatise on the vortex tube. He referred to it as “whirl pipe”, in reference to the movement of air molecules inside the device, which saw modifications in design under Hilsch’s experiments.



Vortex Tube Flow Separations.

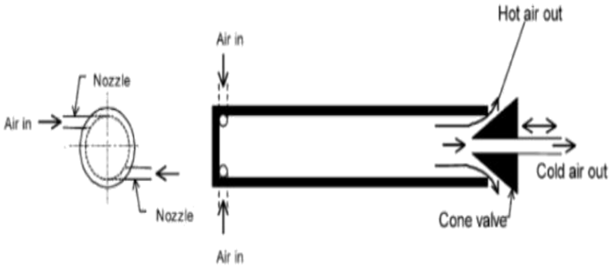
Air cooling and dry machining are both being trialed as possible solutions to the metal cutting industry’s long running problems of extending tool life, reducing tool failure and minimizing the heat generation at the tool tip. To date large amounts of expensive coolant which cause both environmental damage and health hazards have had to be used. The introduction of dry machining is the goal of today’s metal cutting industry that tirelessly endeavors to reduce machining costs and impact from chemicals in the environment. Modern tool tips are already capable of maintaining their cutting edge at higher temperatures, but even with these improvements in tool materials, the cutting edge will eventually break down. Applying cold air to the tool interface of these modern tool tips will also help prolong their tool life reducing the cost of metal cutting. Dry machining incorporating air being directed on to the tool interface is considered in this paper as a possible alternative for harmful liquid-based cooling. Vortex tube is a alternative cooling method and sustainability tool in metal cutting process.

TYPES OF VORTEX TUBE



Counter Flow Vortex Tube

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.



Uni Flow Vortex Tubes

It does not have its cold air orifice next to the inlet 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.

IMPORTANT DEFINITION

1. **Cold mass fraction**:

The cold mass fraction defines the ratio between the mass of air moving out through the cold exit to the actual mass of air entering the vortex tube through the inlet. It is an important parameter which defines the performance and the temperature separation of a vortex tube this is expressed by$\mu c = Mc/Mi$(1.1) Where Mc is the mass flow rate of cold air and Mi is the mass flow rate through the inlet.

2. Cold air temperature drop

Cold air temperature drop is the difference between the temperatures of air at inlet to that of the Temperature of air at cold exit. It is denoted by $\delta Tc = Ti - Tc$(1.2) Where Ti is the temperature of air at inlet and Tc is the temperature of air at cold outlet.

3. Cold orifice diameter ratio

Cold orifice diameter ratio is the ratio between the diameters (d) at the cold exit to that at the inlet (D).

$$\beta = d/D \quad (1.3)$$

4. Coefficient of performance

It is defined as defined as a ratio of cooling rate to the energy used in cooling. It is given by $COP = Qc/W$ (1.4) Where Qc is the cooling rate per unit of air in the inlet vortex tube, and W is mechanical energy used in cooling per unit of air inlet.

RANQUE’S CONTRIBUTION

One of the most comprehensive historical documents detailing the chain of events leading to and analyzing the discovery of the RHVT was documented by C.D. Fulton, shortly after Ranque and Hilsch’s findings. Fulton ascertained that when “Ranque, the discoverer of this technology, presented himself before the Society Franchise Physique in June 1933 and told his audience that hot and cold air came out of opposite ends of a simple piece of pipe, (he) was received with skepticism Aerodynamicists at the time simply came to the conclusion that stagnation temperature had been Confused with static temperature; the two streams weren’t really cold and hot “The theory Ranque gives in the United States patent, was stated as follows, “The rotating gas spreads out in a thick sheet on the wall of the tube and the inner layers of this sheet press upon the outer layers by centrifugal force and compress them, thus heating them. At the same time the inner layers expand and grow cold Friction between the layers is to be minimized”

HILSCH’S CONTRIBUTION

It is thought that Hilsch, physicist of the University of Erlangen, got to know of this device due to information supplied to him from occupied France. Hilsch published an article in 1946 and in it he refers briefly to Ranque’s paper of 1933 as the source of the idea, but it seems that he had not learned of the patent. He had arrived nevertheless at exactly the same design shown in certain of Ranque’s drawings. In this article Hilsch wrote: “The air passing through the orifice has been expanded in the centrifugal field from the region of high pressure at the wall of the tube to a low pressure near the axis. During this expansion it gives considerable part of its kinetic energy to the peripheral layers through increased friction. The peripheral layers then flow away with increased temperature The internal friction causes a flow of energy from the axis to the circumference by trying to establish a uniform angular velocity across the entire cross section of the tube” Following Hilsch, nearly everyone has used similar counter-flow designs to the complete neglect of the uniflow type. This is in part to the fact that a counter-flow type is easier to manufacture and offers two distinct hot and cold outlets at opposite ends of the tube where the thermal output of each cannot interfere with each other. As a consequence of this, the counter flow design is the primary focus of this project.

CONCEPTUAL STUDY OF VORTEX TUBE

In this research examines the parameter of a Ranque-Hilsch vortex tube being used to cool tool tip during machining. The Ranque-Hilsch vortex effect was discovered in the early 1931swhen it caused considerable excitement, as it demonstrated that it was possible to produce hot and cold air by supplying compressed air to a tube. At first it is hard to believe that such a device can produce hot and cold air and at a useful flow rate. The vortex tube is a simple device with no moving parts, which simultaneously produces cold and hot air streams.

Vortex tubes are typically used for their cooling capability in processes such as welding, brazing, solidifying polymers, and controlling air climate. Vortex tubes can be useful in certain situations as they are small, simple to make and repair, and require no electrical or chemical power input. There is no unifying theory that explains the temperature separation phenomenon inside the vortex tube.

HISTORICAL BACKGROUND

The vortex tube was invented by a French physicist named Georges J. Ranque in 1931 when he was studying processes in a dust separated cyclone. It was highly unpopular during its conception because of its apparent inefficiency. The patent and idea was abandoned for several years until 1947, when a germen engineer Rudolf Hilsch modified the design of the tube .Since then, many researchers have tried to find ways to optimize its efficiency. Until today, there is no single theory that explains the radial temperature separation.

TEMPERATURE SEPARATION

The physical mechanism inside an operating vortex tube can be observed physically, but difficult to explain. Compressed air is sent through the inlet nozzle. Swirl generators at the inlet plane create the vortex motion inside the tube. As the vortex moves along the tube, a temperature separation is formed. Hot air moves along the tube periphery, and cold air is in motion in the inner core. The hot air is then allowed to exit through the cone valve at the far end of the tube, while the cold air outlet is next to the inlet plane..

CONCEPT OF THE PROJECT

Computational fluid dynamics (CFD) and experimental studies are conducted towards the optimization of the Ranque - Hilsch vortex tubes. Different types of nozzle profiles and number of nozzles are evaluated by CFD analysis. The optimum cold end diameter (dc) and the length to diameter (L/D) ratios and optimum parameters for obtaining the maximum hot gas temperature and minimum cold gas temperature are obtained through cfd analysis. Demonstrate the ability of a carefully implemented CFD model to predict the measured performance of a commercial vortex tube over a range of parameters. The motivation for this work is the development of a tool that will allow researchers to use CFD to understand effects of modifying the geometry of a vortex tube without resorting to the manufacture and test of numerous design permutations.

SCOPE OF THE PROJECT

This research will improve air-cooling temperature and it can replace traditional cutting fluid for many machining applications, without any reduction in tool life or reduction in quality of work piece surface finish. The introduction of using a Ranquehilsch vortex tube to provide cold air to the tool interface is shown to significantly improve the performance of air-cooling. Recorded tool tip interface temperatures clearly indicate that there is a highlysignificant reduction in tool tip temperature. This reduction in temperature slows the wear mechanisms as shown by the reduced flank wear when examined under a microscope. Therefore, monitoring the growth of the flank wear indicates the increased tool life when being air cooled.

Vortex tubes are typically used for their cooling capability in processes such as welding, brazing, solidifying polymers, and controlling air climate. Cool machining operation cool machining operations, Set solders and adhesives, cool plastic injection molds, dry ink on labels and bottles, dehumidify gas operations , cool heat seal operations,

- Vortex tube use only compressed air for spot cooling no electricity or refrigerants are required.

- Vortex tubes are maintenance free ,Since Vortex Tubes have no moving parts there is no maintenance required.

- Vortex tubes are exceptionally reliable.

- Vortex tubes are compact and lightweight.

OBJECTIVES OF THE PROJECT

The main objective of this project is to optimizing the parameters of vortex tube for increasing the cooling temperature. Inlet pressure will set at different values before the start of each test (from the smallest value to the largest value), and kept constant in the series of run of different angles. In the experiments, angle generators were changed from the largest angle to the smallest angle in the range. After a series run the inlet pressure was changed to the bigger value and experiments were repeated for the same series of the angle generators. Increasing the inlet pressure from the smallest value to the largest and decreasing the angles from the largest angle to the smallest helped to avoid the influence of the remnant heat in the tube and reduced the settling time for measuring the temperature at the hot end, as higher pressure and smaller angle generator produced higher temperature at the hot end of the tube. The increase in the nozzle number and the supply pressure leads to the rise of the swirl/vortex intensity and thus the energy separation in the tube.

- To investigate optimum diameter to the length ratio of the hot side.

- To investigate on the geometrical parameters.

- To redesign the nozzle gas inlet and diffuser of the vortex tube.

LIMITATIONS OF THE PROJECT

- It is nearly impossible to explain and predict the phenomenon inside the vortex tube.

- The mystery topic for the vortex tubes is

  the energy separation effect.

COMPUTATIONAL FLUID DYNAMICS INTRODUCTION

Computational Fluid Dynamics or CFD is a computer-based tool for simulating the behavior of systems involving fluid flow, heat transfer, and other related physical processes. CFD is now regarded as the “third” technique for the solution of fluid flow problems, complementing, but not replacing, the well-established approaches of theory and experiment. It is a relatively new branch of fluid mechanics and finds its niche in predicting fluid flows that are difficult or impossible to analyze using theory and are complex, time consuming, or expensive to measure experimentally.

Computational - mathematical analysis, computing

Fluid Dynamics - the dynamics of things that flow

CFD - a computational technology that enables one to study the dynamics of things that flow. CFD is concerned with numerical solution of differential equations governing transport of mass, momentum and energy in moving fluid. Using CFD, one can build a computational model on which physics can be applied for getting the results. The CFD software gives one the power to model things, mesh them, give proper boundary conditions and simulate them with real world condition to obtain results. Using CFD a model can be developed which can breed to give results such that the model could be developed into an object which could be of some use in our life.

THE HISTORY OF CFD

Computers have been used to solve fluid flow problems for many years. Numerous programs have been written to solve either specific problems, or specific classes of problems. From the mid-1970s, the complex mathematics required to generalize the algorithms began to be understood, and general purpose CFD solvers were developed.

These began to appear in the early 1980s and required what were then very powerful computers, as well as an in-depth knowledge of fluid dynamics, and large amounts of time to set up simulations. Consequently, CFD was a tool used almost exclusively in research. Recent advances in computing power, together with powerful graphics and interactive 3-D manipulation of models have made the process of creating a CFD model and analyzing results much less labor intensive, reducing time and, hence, cost. Advanced solvers contain algorithms which enable robust solutions of the flow field in a reasonable time. As a result of these factors, CFD is now an established industrial design tool, helping to reduce design timescales and improve processes throughout the engineering world. CFD provides a cost-effective and accurate alternative to scale model testing, with variations on the simulation being performed quickly, offering obvious advantages.

USES OF CFD

CFD is used by engineers and scientists in a wide range of fields. Typical applications include:

- Process industry: Mixing vessels and chemical reactors
- Building services: Ventilation of buildings, such as atria
- Health and safety: Investigating the effects of fire and smoke
- Motor industry: Combustion modeling, car aerodynamics
- Electronics: Heat transfer within and around circuit boards
- Environmental: Dispersion of pollutants in air or water
- Power and energy: Optimization of combustion processes
- Medical: Blood flow through grafted blood vessels

CFD works by solving the equations of fluid flow (in a special form) over a region of interest, with specified (known) conditions on the boundary of that region. The governing equations of CFD utilize adapted forms of the governing equations of fluid flow and heat transfer which are given below for Cartesian co-ordinates.

THE BENEFITS OF CFD

There are three reasons to use CFD software: insight, foresight, and efficiency. Insight Think of an object which is difficult to produce practically and do some experiment on it. CFD provides the break through. Using the CFD software, one can easily design the object and use the boundary conditions to get output. The simulation thus helps in getting results much easily than constructing the real object. Foresight in CFD first we make the model then use certain boundary conditions to get the output. Thus using CFD we can give some real world condition say as pressure or temperature and simulate things to get the output. Many variations can be adopted till an optimal result is reached. All of this can be done before physical prototyping and testing. Efficiency The analysis gives better idea of, how the object works. So necessary changes could be brought about to facilitate better production of the product.Thus CFD helps to design better and faster bringing about improvement in each step.

BOUNDARY CONTITION

In mathematics, any solution to a set of differential equation (PDE’s) requires a set of boundary conditions for closure and the solution of the governing conditions for closure and the solution of the governing equation is no exception.

CFD simulation largely depends on the boundary conditions specified; hence correct boundary and initial conditions, however, can give convergence although not to correct solution. There are wide variety of boundary type available in FLUENT, but only those used in this study will be given.

Flow inlet and exit boundaries

Pressure inlet: Used to define the total pressure and other scalar quantities at flow inlet.

Pressure outlet: Used to define the static pressure at flow outlet (and also other scalar variables, in case of back flow). The use of a pressure outlet boundary condition in stand of an outflow condition often the result in a better rate of convergence when backflow occurs during iteration. Note that when backflow occurs, this boundary act likes a pressure inlet boundary.

CONVERGENCES

Convergence of a flow or heat problem can be judged by observing the normalized residuals. Residuals are numerical imbalance from the solved governing equation resulting from an incomplete solution during the iterative process. The solution process can be terminated when the normalized residuals fall below a specified value, which is generally 10-3. However, in some cases even with the convergence criteria(as far as normalized residuals are concerned) satisfied, the solution may not necessarily be a correct one. To avoid such instances, quantities such as mass flow rate; static pressure and heat flex can be monitored quantity is observed until the change from iteration is negligible thus ensuring good convergence.

BACKGROUND ON THE CFD SOLVER USED (FLUENT)

FLUENT is a finite volume (FV) solver that can handle a wide variety of flow problems such as external flow, internal flow, and two phase flow. All modes of heat transfer can also be solved by the CFD code. This code is used for all CFD analyses throughout this study.

Modern CFD packages are user friendly with improved user and code interfacing. Thus understanding the underlying principles of flow is important in order to put the code to good use. FLUENT has a facility for coding to make repetitive simulation, as in an optimization loop, more efficient and hence save the time. This facility makes use of a journal file, which is a file containing a list of

- Definition of fluid properties.
- Specification of appropriate condition at cells, which coincide with or touch the domain boundary.

SOLVER

The numerical method that form the basis of the solver perform the following steps:

- Approximation of the unknown flow variables by means of simple function
- Discretisation by substitution of the approximations into the governing flow equation and subsequent mathematical manipulation.
- Solution of the algebraic equation.

POST PROCESSOR

CFD packages are now equipped with versatile data visualization tool. These include

- Domain geometry& grid display.
- Vector plot.
- Line and shaded contour plot.
- 2D & 3D surface plots.
- Particle tracking.
- View manipulation (Translation, Rotational, Scaling).
- Color postscript output.

PROBLEM SOLVING STEPS

Once you have determined the important features of the problem you want to solve, you will follow the basic procedural steps shown below.

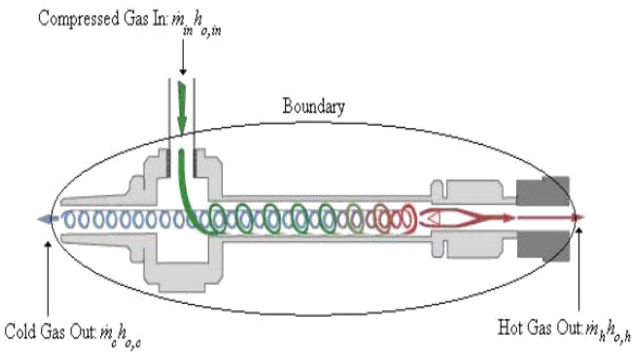
1. Creating the model geometry and grid.
2. Starting the appropriate solver for 2D or 3D modeling.
3. Importing the grid.
4. Checking the grid.
5. Selecting the solver formulation.
6. Choosing the basic equation to be solved: laminar or turbulent (or in viscid), chemical species or reaction, heat transfer, etc. identity additional models needed: fans, heat exchanger, porous media, etc.
7. Specifying material properties.
8. Specifying the boundary conditions.
9. Adjusting the solution control parameters.
10. Initializing the flow field.
11. Calculating a solution.
12. Examining the result.
13. Saving the result.

THERMODYNAMICS OF THE RANQUE HILSCH VORTEX TUBE

When first introduced to vortex tube technology, it would appear that there has been a violation of the laws of thermodynamics. It would seem that there is an internal heat flux without any work input. As in any refrigeration process, work input is paramount to its operation. Herein lies the crux of the problem, and the almost century long quest to fully understand the operation of the tube. The First Law of Thermodynamics can be written as follows, “When a system undergoes a thermodynamic cycle then the net heat supplied to the surroundings plus the net work input to the system from its surroundings is equal to zero” Mathematically this statement is written as

$$\sum Q + \sum W = 0 \quad (4.1)$$

Where Q and W denote the heat supplied and work input to the system respectively. From this First Law the steady flow energy equation can be applied to the RHVT's boundary.



Vortex Tube Inlet and Outlet

Resulting in an equation of the following form

$$\dot m_{in} \left(h_{s,in} + \frac{U_{in}^2}{2} + Z_{in} \right) + \dot Q + \dot W = \dot m_c \left(h_{s,c} + \frac{U_c^2}{2} + z_c \right) + \dot m_h \left(h_{s,h} + \frac{U_h^2}{2} + Z_h \right) \quad (4.2)$$

where $\dot m$, h_o , h_s , U, Z, $\dot Q$ and $\dot W$ denote the mass flow rate, the total enthalpy, the static enthalpy, the velocity vector, the height above the datum, the rate of heat and work inputs supplied respectively, and the subscripts in, c and h denote the inlet, cold and hot outlets respectively.

By using some simple elimination of a few equal and negligible terms, the steady flow energy equation reduces to a reversed adiabatic mixing equation[17] with use of the following steps

1. Combining static enthalpies and kinetic energies into total enthalpy.

2. Acknowledging that the potential energies at each point are approximately the same.

3. There is no heat or work input.

The reversed adiabatic mixing equation is as follows, and it shows that the RHVTdoes indeed satisfy the first law, as energy is conserved

$$\dot m_{in} h_{o,in} = \dot m_c h_{0,c} + \dot m_h h_{o,h} \quad (4.3)$$

This can be reduced further by introducing the ratio used to describe the ratios of cold and hot gas flows as compared to the supplied gas flow; this ratio is called the cold gas fraction

$$\mu_c = \frac{\dot m_c}{\dot m_{in}} \quad (4.4)$$

This is easily recognized by dividing Equation by the inlet mass flux $\dot m_{in}$

$$h_{o,in} = \mu_c h_{o,c} + (1 - \mu_c) h_{o,h} \quad (4.5)$$

If the gas flowing through the RHVT is treated approximately as an ideal gas and changes in kinetic energy are neglected we can write the above conservation equation as follows

$$c_p T_{o,in} = \mu_c c_p T_{o,c} + (1 - \mu) c_p T_{o,h}$$

(4.6)

Where c_p and To are the specific heat capacity at constant pressure and the total temperature respectively. Dividing across by c_p

$$T_{o,in} = \mu_c T_{o,c} + (1-\mu)\, T_{o,\,h} \tag{4.7}$$

We get results in a rather simplistic energy balance equation, but it does illustrate quite clearly that when considered as a system with boundaries the RHVT does indeed satisfy basic thermodynamic rules. A much broader perspective of the system needs to be conducted to show that the Second Law of Thermodynamics is satisfied[9], i.e. that “it is impossible to construct a device that operating in a cycle will produce no effect other than the transfer of heat from a cooler to a hotter body” . As there is no mechanical work input to a RHVT, and yet there is a heat flux[16], to obey the above two classic laws of thermodynamics; there must be a supply of work of some other form. The source of this work has been the main argument since the establishment of this technology.

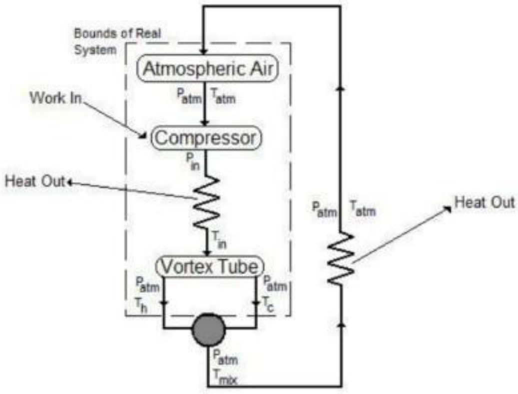


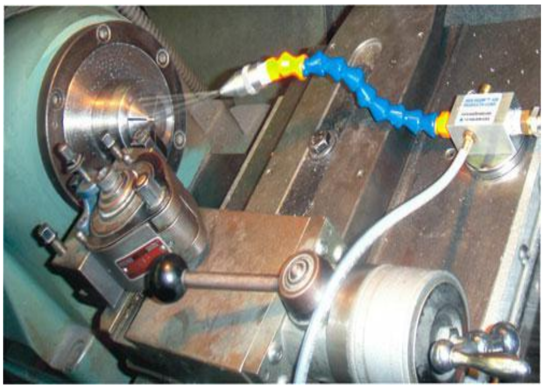
Fig 4.2 Experimental Setup Analysis of the complete RHVT

system from the source of the flow potential, as in the compressor supply, to the exit of the two streams of hot and cold air, gains a different perspective. The system is now viewed from the suction of atmospheric air through the compressor, channeled through the supply piping and back to the atmosphere[15], through both exits of the RHVT. It is now is easier to see that the RHVT does indeed satisfy the second law above wu et al[8], and that equilibrium is indeed maintained, in that the compressed air does indeed return to atmospheric conditions, once it has completed its cycle. Fig shows the RHVT as a complete system does indeed satisfy the second law of thermodynamics.

FLUID DYNAMICS OF THE RANQUE – HILSCH VORTEX TUBE

In a RHVT a high pressure fluid, mainly compressed air, enters the tube and passes through nozzles achieving a high angular velocity and hence causing a vortex type flow, There are two outlets to the tube: the hot outlet Is placed near the outer radius of the tube at the end away from the inlet nozzles and the cold outlet is placed at the centre of the tube at the same end as the air inlet. By adjusting a control valve downstream of the hot outlet it is possible to vary the fraction of the incoming flow that leaves through the hot outlet on the periphery of the tube[14]. The proportion of cold gas deflected back through the cold outlet is referred to as the cold fraction µc, previously defined in Equation. By varying the cold fraction the cold outlet total temperature drop can be adjusted.

VORTEX TUBE MACHINING APPLICATION

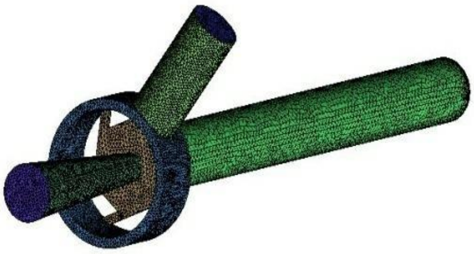


and feed rates on dry machining operations. The effective cooling from a Cold Air Gun can eliminate heat-related parts growth while improving parts tolerance and Surface finish quality Commercial vortex tubes are designed for industrial applications to produce a temperature drop of about 26.6 °C (48 °F). With no moving parts, no electricity, and no Freon, a vortex tube can produce refrigeration up to 6,000 BTU (6,300 kJ) using only filtered compressed air at 100 PSI (689 kPa). A control valve in the hot air exhaust adjusts temperatures, flows and refrigeration over a wide range.

Vortex tubes are used for cooling of cutting tools (lathes and mills, both manually-operated and CNC machines) during machining. The vortex tube is well-matched to this application: machine shops generally already use compressed air, and a fast jet of cold air provides both cooling and removal of the "chips" produced by the tool.

CFD ANALYSIS

vortex tube used for machining application Most popular applications involve cooling during the machining of metals, plastics, wood, rubber, ceramics and other materials. Cold air machining outperforms mist coolants and substantially increases tool life



Tetra Mesh

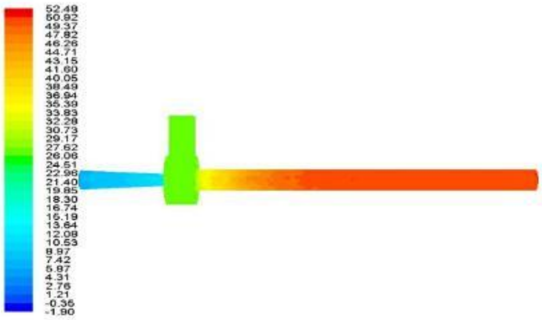
The present work is done using ansys fluent 14.5; it is the volume based solver. The solver used 3 dimensional steady, compressible, pressure based setup, density based solver diverged for this vortex tube problem, energy equation is on for capture the energy and temperature distribution. K-epsilon model 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[11]. The fluent package solved by mass, momentum and energy equation.

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[6] 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[10], the negative pressure created inside the cold end important for back flow.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.

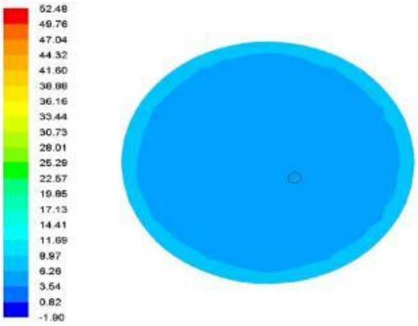
RESULT AND DISSCUSTION

The various results are obtained from the analysis fluid flow in vortex tube is discussed in this chapter. The temperature at the cold end and hot end is taken as output.



Exair 3205 Model Temperature Contour

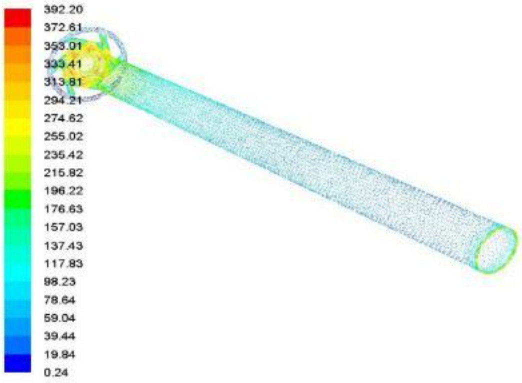
Total Temperature in °c Fig 6.1 shows that the hot air coming out in one end and cold air coming out in another end for the Exair 3205 medium type vortex tube having the L/D ratio of 11.37.



Exair Cold End Temperature Contour

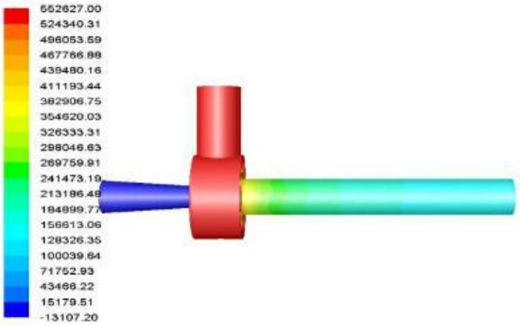
Velocity Vector Of The 116mm Length

Vortex Tube

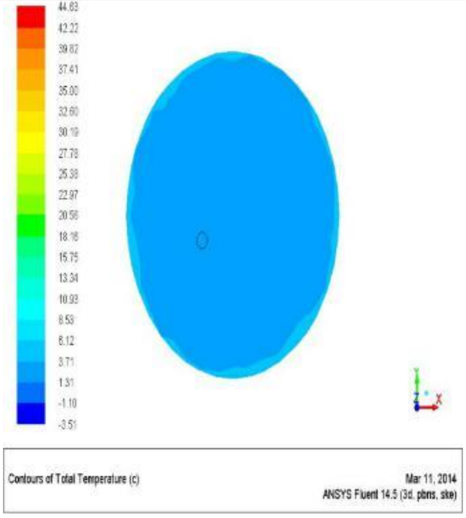


Velocity Vector Of The 145mm Length

Tube



Pressure Contour of L/D-5.39 Fig 6.6 shows the total pressure contour of the vortex tube .in the cold end negative pressure is created that is the reason for the back flow in the vortex tube.



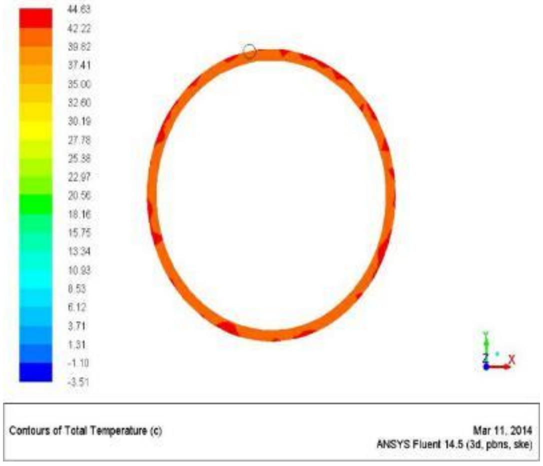


Fig 6.9 Cold End and Hot End Temperature Contour Of L/D Radio 5.39 and Orifice Radios 2mm and Hot End Out 0.4mm

The hot end gap is 0.3mm for existed model reducing the hot end gap to 0.2mm increase the temperature at cold end. 0.4mm hot end gap gives the minimum cold end temperature 1.31°c

CONCLUSION

This work shows that reduction in length of the vortex tube will reduce the cold end temperature, because reduction in length of the vortex tube will affect the velocity inside the vortex generator and tube. Orifice diameter is modified and analyzed, increasing the orifice diameter increasing the temperature at cold end. Reducing orifice radios to 2mm and 1.5mm give the cold end temperature, reducing the orifice radios below 1.5mm increasing the temperature at cold end. Hot end gap at 0.4mm give the optimum temperature 1.31°c.

PUPLICATION

[1] Presented a paper entitled optimizing L/D ratio of vortex tube through CFD analysis for sustainable manufacturing in the national conference on recent trends in mechanical engineering.

[2] Presented a paper entitled optimizing the parameters of vortex tube through CFD analysis for sustainable manufacturing in national conference on trands in automotive parts systems and applications.

[3] Presented a paper entitled optimizing the parameters of vortex tube through CFD analysis for sustainable manufacturing in the international conference on trends in engineering and management.

[4]Published a paper in IOSR Journal of

Mechanical and Civil Engineering international journal entitled optimizing the parameters of vortex tube through CFD analysis for sustainable manufacturing e-ISSN:2278-1684,p-ISSN:2320-334X PP 06-12.

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