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TO INVESTIGATE THE EFFECT OF SPINNER GEOMETRY ON COP OF VORTEX TUBE REFRIGERATION

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Abstract - *The vortex tube is a simple device used in industry for generation of cold and hot air streams from a single compressed air supply. This simple device is very efficient in separation of air streams of different temperatures. Any fluid (air) that flows and rotates about an axis such as a tornado, is called a vortex. A vortex tube creates a vortex and separates it into two air streams-one hot and one cold. Figure shows how a vortex tube works. Compressed air enters a cylindrical chamber which causes the air to spiral. At the end of the hot tube, a small portion of this air exits through a needle valve as hot air. The remaining air is forced back through the center of the cylindrical tube. This super-cooled air flows through the center of the generator and exits through the cold port and is the required part of our project.*

The geometry of vortex tube changes in this experiment is spinner notches angle which is situated inside the vortex tube after nozzle. Due to this part the flow of vortex (tornado) form. The angle taken of spinner notches is upto 45 degree. So by changing the different angles (25, 35, 45 degree) the variations in temperature is obtained and COP of vortex tube may be increased.

Key Words: *VORTEX TUBE, COP, TEMPERATURE, CFD ANALYSIS*

1. INTRODUCTION

The primary objective for this experiment is to determine the coefficient of performance (cop) of vortex tube by changing the geometry of vortex tube, inside the vortex tube there is a spinner notches which has an definite angle, by changing the angle of this spinner notches the cop may varied. The analysis of this phenomenon is done by using ANSYS CFD FLUENT software.

CFD has a full form of Computational Fluid Dynamics, but it's scopeis not only limited to fluid dynamics. So, when we say computational fluid dynamics, weessentially mean computational transport phenomena, so which involve computational fluid dynamics, heat transfer, mass transfer or any process which involves transport phenomena with it.

On CREO PARAMETRIC the three cad model of vortex tube can be made of notches spinner angle of 25˚, 35˚ and 45˚. This models is then call on ANSYS CFD software and analysis will be carry out at different pressures. The minimum cold temperature obtained on any of the model of vortex tube is the efficient vortex tube. COP of all the models of vortex tube is calculated by doing simple calculations and the maximum COP obtained by this calculation based on the temperature is the final result is this experiment.

2. LITERATURE REVIEW

Early in the nineteenth century, the great physicist James Clerk Maxwell imagined that someday we might be able to get hot and cold air with the same device with the help of a "friendly little demon" who would sort out and separate the hot and cold molecules of air (Cockreill, 1995). Later his dream had come true. The "friendly little demon" is called vortex tube in 1928, a French physics student George Ranque occasionally found the phenomenon of energy separation in the vortex tube during his experiment with a vortex-type pump developed by him. He noticed that the warm air would be drawn from one end, and the cold air from the other. Later it was discovered that the mechanism is closely related to the swirling flow of the air within the tube. Air molecules in the swirl near the wall of the tube tend to have higher velocity compared to those in the central region of the tube. After energy separation in the vortex tube, the inlet air stream was separated into two air streams: hot air stream and cold air stream, the hot airstream left the tube from one end and the cold air stream left from another end. The outlets from where the hot and cold air streams leaving the tube are called the hot and cold end respectively.

In this experimental study of the vortex tube performance has been carried out to investigate the parameters affecting vortex tube operation. Four cases has been studied, in which the influence of the tube length L, the number of entrance nozzles NZ, Cold air orifice diameters d_c and inlet pressure under various condition. The effects on these parameters on the Hot and Cold outlet temperature as function of cold air mass ratio (€) are discuss and presented. And also the coefficient of performance (COP) Of the vortex tube as a refrigerator and as a heat pump has been calculated.

PROCEDURE FOR ANALYSIS

A. Creo Modeling of Vortex Tube

Steps for making the creo model :

1. First step for doing analysis is to create the CAD model of the component on which we want to do analysis.
2. Open the creo software & set the working directory
3. Go to file & select the new.
4. Select the part molding option. Give the name as vortex tube & click on ok
5. There are 3 datum planes are present from which we have to select the front plane

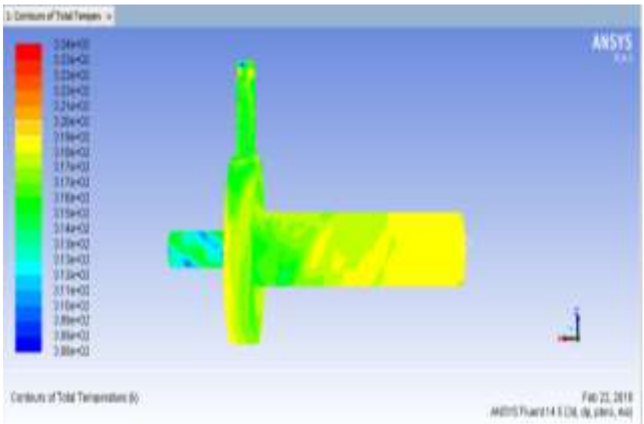
B. Meshing

Meshing is an integral part of the computer-aided engineering simulation process. The mesh influences the accuracy, convergence and speed of the solution. In our experiment the meshing is done on each point of vortex tube and the type of meshing is unstructured triangular meshing.For doing this, the first step is to double-click on meshing underneath the fluid flow (fluent) just below the geometry option.After double-click on meshing the page of meshing is open and the geometry of vortex tube is shown.

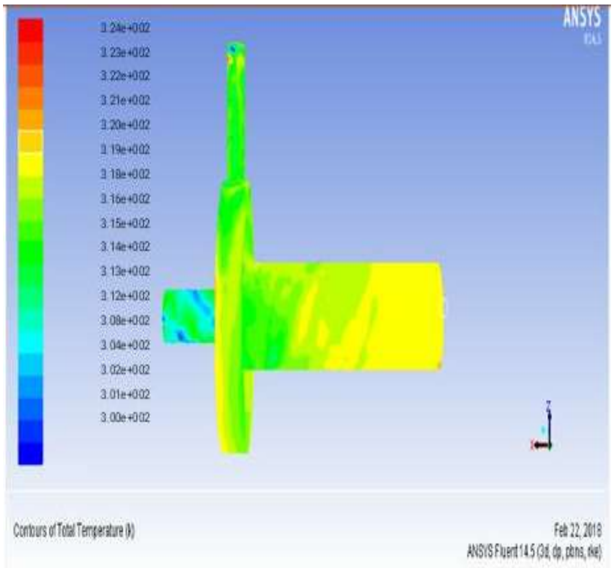
Observation and Calculation

Case 1 Notches Spinner Angle= 25˚

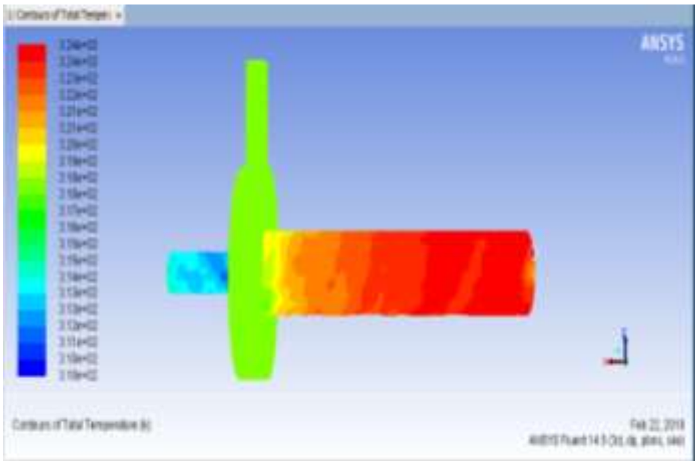
Case 1: 5 bar pressure (Angle 25˚)



Case 2: 5 bar Pressure (Angle= 35˚)



Case 3: 5 bar Pressure (Angle= 45˚)



1. **Calculation:-**

I. Cold Drop Temperature (Δ Tc)
Δ Tc = Tin– Tc
= 35 – 28
Δ Tc = 7˚c

II. Hot Raise Temperature (Δ Th)
Δ Th =Th - Tin
Δ Th = 48 – 35
Δ Th = 13˚c

III. Temperature Drop at the Two Ends (ΔT)
ΔT = Th – Tc
ΔT = 48 – 28
ΔT = 20˚c

IV. Cold Mass Fraction (μ)

$$\mu = \frac{\Delta \text{ Th}}{\Delta \text{ Tc}}$$

$\mu = \frac{13}{13+7}$

$\mu = 0.65$

(65% of cold air is coming from cold side and 35% of hot air is coming from hot side)

V. Static Temperature Drop due to Expansion (Δ T'c)

$$\Delta T'c = Ti^* \left[1 - \left(\frac{Pa}{Pi}\right)^{\frac{(\gamma-1)}{\gamma}}\right]$$

$$\Delta T'c = 35^* \left[1 - \left(\frac{1}{5}\right)^{\frac{1.4-1}{1.4}}\right]$$

Δ T'c = 12.90°C

VI. Relative Temperature Drop (ΔTrel)

$$\Delta Trel = \frac{\Delta Tc}{\Delta T'c}$$

$$\Delta Trel = \frac{7}{12.90}$$

ΔTrel = 0.55

VII. Vortex Tube Adiabatic Efficiency (η_{ab})

$$(\eta_{ab}) = \frac{\text{Actual cooling in vortex tube}}{\text{Cooling possible with adiabatic expansion}}$$

$$(\eta_{ab}) = \frac{\mu}{\Delta Trel}$$

(η_{ab}) = 0.36

VIII. Adiabatic Compressor Efficiency(η_{ac})

(η_{ac}) = 0.61

∴Coefficient of Performance (C.O.P)

$$COP = \eta_{ab} {}^* \eta_{ac} {}^* \left[\left(\frac{Pa}{Pi}\right)^{\frac{1.4-1}{1.4}}\right]$$

$$COP = 0.36^*0.61^* \left[\left(\frac{1}{5}\right)^{\frac{(1.4-1)}{1.4}}\right]$$

COP = 0.189 ≈ 0.2

∴COP = 0.2

RESULT

After doing Analysis, Observations and Calculations, the some of the results are obtained at three cases.

A. Case 1:

1. Notches Spinner Angle = 25°
   i. Inlet Pressure = 5 bar
   ii. Cold out Temperature = 308k = 35°C
   iii. Hot out Temperature = 320k = 47°C

   The COP of Vortex Tube obtained at 5 bar Pressure in case 1 is
   COP = 0.05
2. Notches Spinner Angle = 25°
   i. Inlet Pressure = 6 bar
   ii. Cold out Temperature = 306k = 33°C
   iii. Hot out Temperature = 317k = 44°C

   The COP of Vortex Tube obtained at 6 bar Pressure in case 1 is
   COP = 0.04

B. Case 2:

3. Notches Spinner Angle = 35°
   iv. Inlet Pressure = 5 bar
   v. Cold out Temperature = 301k = 28°C
   vi. Hot out Temperature = 321k = 48°C

   The COP of Vortex Tube obtained at 5 bar Pressure in case 2 is
   COP = 0.2
4. Notches Spinner Angle = 35°
   vii. Inlet Pressure = 6 bar
   viii. Cold out Temperature = 302k = 29°C
   ix. Hot out Temperature = 317k = 44°C

   The COP of Vortex Tube obtained at 6 bar Pressure in case 2 is
   COP = 0.1

C. Case 3:

5. Notches Spinner Angle = 45°
   x. Inlet Pressure = 5 bar
   xi. Cold out Temperature = 311k = 38°C
   xii. Hot out Temperature = 324k = 51°C

   The COP of Vortex Tube obtained at 5 bar Pressure in case 3 is
   COP = 0.04
6. Notches Spinner Angle = 45°
   xiii. Inlet Pressure = 6 bar
   xiv. Cold out Temperature = 310k = 37°C
   xv. Hot out Temperature = 332k = 59°C

   The COP of Vortex Tube obtained at 6 bar Pressure in case 3 is
   COP = 0.06

In above results the different temperatures and COP of vortex tube is obtained at different pressure and different geometry of vortex tube.

Conclusion

From the above Results we conclude that at different geometry of notches spinner the cop of vortex tube varied. The notches spinner angle is 25˚, 35˚, and 45˚ and both giving different results at the different pressures.

The working pressure we used in our experiment is 5 bar

A. Case 1: [25˚ spinner angle]

a. The cop of vertex tube obtained at 5 bar pressure in case 1 is

COP = 0.05

b. The cop of vortex tube obtained at 6 bar pressure in case 1 is

COP = 0.04

B. Case 2: [35˚ spinner angle]

c. The cop of vortex tube obtained at 5 bar pressure in case 2 is

COP = 0.2

d. The cop of vortex tube obtained at 6 bar pressure in case 2 is

COP = 0.1

C. Case 3: [45˚ spinner angle]

e. The cop of vortex tube obtained at 5 bar pressure in case 3 is

COP = 0.04

f. The cop of vortex tube obtained at 6 bar pressure in case 3 is

COP = 0.06

From the above results we observed that as the pressure increases the cop decreases. So, the maximum cop of vortex tube is obtained at case 2 which is 0.2 and this cop is obtained at 5 bar pressure.

So, the final result of our experiment is obtained at case 2.

In case 2 the spinner angle of vortex tube is 35˚ which is the best angle for making the compressed air in spiral form.

Due to this angle the cold temperature obtained is less upto 28˚. And this temperature is able to make normal temperature at hot places.

Therefore, we conclude that in case 2 at 5 bar pressure which has the spinner angle of 35˚ is the best design of vortex tube. And the cop obtained by this design vortex tube after analysis CFD software is 0.2.

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