OPTIMIZING THE PTFE TEFLON VORTEX TUBE PARAMETERS USING TAGUCHI TECHNIQUE

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ABSTRACT- **Vortex tube is a mechanical device that separates compressed gas into hot and cold streams. When high pressure air enters into the vortex chamber through one or more tangential nozzles, a strong vortex flow created which splits into two regions. The high temperature air near the boundary of the tube leaves circumferentially through the conical valve where as the air at lower temperature leaves through the cold orifice. A conical valve is adjusted with the hand control knob allows for adjusting the volume and temperature of air coming out from the cold end. There is no maintenance, no mess, no explosion hazard, no electricity, and no moving parts in using the vortex tube. Vortex tubes behave in a very predictable and controllable way. The only disadvantage with the vortex tube is its low coefficient of performance (COP).**

The Vortex tube used for experimental work is manufactured using composite material Poly Tetra Fluoro Ethylene (PTFE TEFLON RODS). An Experimental work has been carried out to analyze the performance of vortex tube that influences the effect of five controllable input variables namely diameter of the orifices, diameter of the nozzles, length of hot tube, tube diameter and inlet pressure over the temperature difference in the cold side as output using Taguchi Method. Experiments were conducted at different input pressures of air, viz., at 2, 4 and 6 bars and for different diameters of orifices, viz., 5 mm ,6.5 mm and 8 mm. The source for compressed air input to the vortex tube was reciprocating air compressor. The various Parameters like main effect analysis, analysis of variance (ANOVA) and Optimal Cold Temperature were carried out in order to determine the effects of process parameters and optimal factor settings. Finally, the confirmation test is carried out to verify the accuracy of Taguchi method.

key words: **Vortex tube, geometrical parameters, orifice diameter ,tube length, Taguchi method.**

I.*INTRODUCTION:*

The Vortex Tube is an efficient and low value resolution to a good kind of industrial spot cooling and method cooling desires. The Vortex tube could be a device that produces cooling at one finish and heating at the opposite finish at the same time. The extremely compressed gas is forcing through a generation chamber, and by the virtue of high and restricted volume the pressure head of feeding air is get reborn into the kinetic head that generates the centrifugal spin of air on the inner walls of the tube. The schematic diagram of Vortex tube is shown in figure one. it's no moving parts; pressurized gas is injected tangentially into a swirl chamber and accelerates to a high rate of rotation

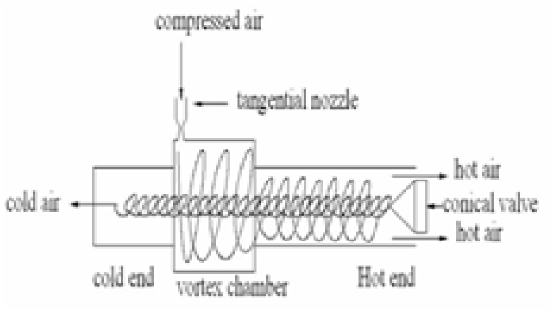

Figure 1: Schematic diagram of Vortex tube

The Compressed air which is supplied to the vortex tube and passes through nozzles that are tangent to an internal counter bore. These nozzles set the air in a vortex motion. This spinning stream of air turns 90° and passes down the hot tube in the form of a spinning shell, similar to a tornado Due to the conical nozzle at the end of the tube, only the outer shell of the compressed gas is allowed to escape at that end. The remainder of the gas is forced to return in an inner vortex of reduced diameter within the outer vortex. A percentage of the hot, high-speed air is permitted to exit at the control valve. The remainder of the (now slower) air stream is forced to counter flow up through the center of the high-speed air stream, giving up heat, through the center of the generation chamber finally exiting through the opposite end as extremely cold air. For the performance analysis of this kind of vortex tube is being made on the basis of some series of different-different mechanical, physical and constructional features

II.*MATERIAL USED IN MANUFACTURING VORTEX TUBE:*

The Vortex tube used for experimental work is factory-made mistreatment material is **Poly Tetra Fluoro Ethylene** (PTFE TEFLON RODS) as shown in figure below .PTFE TEFLON rods having temperature confrontation is 260^0c and pressure with stand able capable of 35bar.

figure :2.vortex tube with PTFE Teflon material.

III .*EXPERIMENTAL STUDY:*

In this study, a counter flow type Ranque–Hilsch vortex tube with (L=180 mm, D =25mm) L/D ratio equal to 8 was used. Three different orifices (5mm ,6.5mm ,8mm) with different nozzle numbers (11mm, 14mm ,17mm) have been manufactured and used in the experiments as shown in figure. Each one of the nozzles has the same constant square cross-section .

figure: 3. orifices used in the experiments.

The mass flow rates at the cold and hot outlets of the counter flow Ranque–Hilsch vortex tube have been measured by use of a rotameter. The temperatures of the pressurized oxygen at the inlet, and the cold and hot outlets were measured by use of a thermometer with ±0.5 ^{0}C precision tolerances, and the obtained temperature values have been converted into Kelvin (K) unit.

Temperature probes of the thermometer were placed into the hole which was drilled at the center of the counter flow Ranque– Hilsch vortex tube and away from the cold and the hot outlets. A control valve has been mounted on the hot outlet of the tube in order to adjust the mass flow rate of the hot air. Before starting the experimental studies, the control valve on the hot outlet was kept in fully open position.

IV. *TAGUCHI TECHNIQUE APPLIED TO VORTEX TUBE:*

By applying taguchi technique, the performance of vortex tube will be optimized simply. the amount of iterations to conduct the experiment will be reduced. the chance issue decreases. in our experiment, we tend to used static style considering no noise factors. the atomic number 50 magnitude relation is predicated on “smaller is better”, since we've got to optimize the result to induce minimum cold temperature.

A). ORTHOGONAL ARRAYS (OAS):

in choosing associate acceptable OA, the pre-requisites area unit (ross, 1988; roy, 1990):

- selection of method parameters and or interactions to be evaluated.
- selection of range of levels for the chosen parameters.

the determination of that parameters to research hinges upon the merchandise or method performance characteristics or responses of interest (ross, 1988). many ways area unit steered by taguchi for determinant that parameters to incorporate in associate experiment. these area unit (ross, 1988):

- group action
- flow charting
- cause-effect diagrams

taguchi orthogonal arrays area unit experimental styles that typically need solely a fraction of the full-factorial combos. several orthogonal arrays area unit on the market in alternative forms, like aliquot factorial and plackett-burman styles. the arrays area unit designed to handle as several factors as potential during a sure range of runs. the columns of the arrays area unit balanced and orthogonal. this suggests that in every try of columns, all issue combos occur a similar range

of times. orthogonal styles permit united states of america to estimate the result of every issue on the response severally of all alternative factors. taguchi has given normal organization of american states for 2 level and 3 level factors which will accommodate handful range of things for experimentation. reckoning on the amount of things planned and levels for the factors, appropriate OA will be chosen from. in our gift work, we've got chosen l-27 array to hold out experiments.

V. *CONTRIBUTION EXPERIMENTAL WORK:*

A). DESCRIPTION:

The arrangement of the experimental system as well as the measuring devices of a vortex tube square measure shown within the below figure. The system consists of a vortex tube chamber with the tangential water nozzle or vortex generator, cold passageway plate, cone formed valve, thermometer, water valve, compressor severally. throughout the take a look at, the compressed gas was discharged from associate degree compressor through the gauge with the assistance of a bearing valve before coming into the RHVT at a given water pressure. within the RHVT, the air is separated into 2 streams with low and high temperatures.

The cold air leaves the RHVT through the cold passageway plate put in close to the water nozzles, whereas the recent air at liberty at the top of the recent tube equipped with the cone formed valve. The temperatures square measure noted by victimization measuring device. the road diagram of the experimental started is shown below Figure .

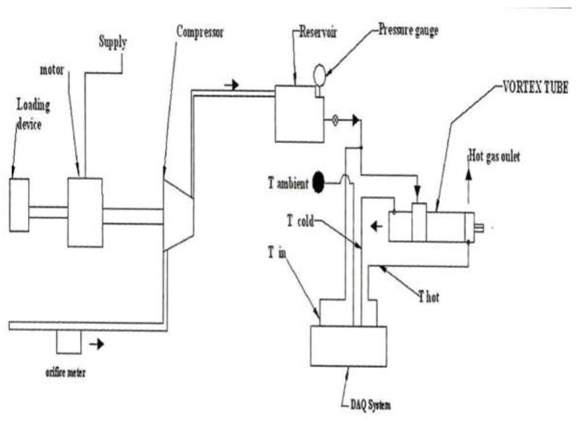

Figure:4. Line diagram of Experimental setup.

The experimental setup consists of 2 stage mechanical device, gauge, vortex tube and temperature measuring instrument. a bearing valve at the mechanical device reservoir exit controls the water air to the vortex chamber. The water pressure is measured victimization gauge. The temperatures of the air at cold finish and close air square measure measured victimization thermometer. Experimental work has been distributed to research the cooling impact of vortex tube at totally different combos of pressures, passageway diameters, nozzle diameters, Vortex tube diameters, and lengths of the Vortex tube. The temperature of air at cold and hot ends was measured with digital in addition as analog thermometers to avoid errors. All the instruments were label before the measurements were truly determined recorded. The operative parameters noted throughout the experiment for every vortex tube style were:

- Air pressure close to water to vortex tube in bars.
- Cold air temperature in oC.

The aim of the experiment is to ascertain the variation of temperature at cold end with respect to varied operative and geometrical parameters and determination of its quality to air conditioning applications and springing up with experimentation on that.

The components i.e., inlet tube, main body (flange), cold tube, hot tube, nozzle, diaphragm, management worth

square measure fitted one by one. The mechanical device is studied and therefore the Pressures square measure maintained. The settled vortex tube is placed on the table and therefore the outlet of the mechanical device is hooked up to the water of the equipment. initial the mechanical device is maintained at a pressure of two bar and therefore the air is allowed to taste the water and that we need to sit up for five minutes. when this the thermometers square measure placed at each the ends and therefore the readings square measure noted. The temperature of water air is additionally noted down employing a digital measuring device.

Then the mechanical device pressure is accrued to four bar and therefore the readings square measure taken in an exceedingly similar manner. The procedure is followed up to six bar. The readings square measure tabulated as shown. when taking the readings with all the diaphragms, the recent tube is modified that as totally different Lengths. The experiment is distributed in an exceedingly similar manner for all hot tubes. **the software used for analysis and optimization is MINITAB 16.**

VI. *RESULTS AND CONCLUSIONS:*

A). CHOICE OF ORTHOGONAL ARRAY AND PARAMETER ASSIGNMENT

For this experimental work the 5 method parameters every at 3 levels are determined. it's fascinating to own 3 minimum levels of method parameters to mirror truth behavior of output parameter of study. the method parameters area unit renamed as factors and that they area unit given within the adjacent column. the degree of the individual method parameters/factors area unit given in Table .

Table.1:method Parameters and their Levels

Factors	Parameters	Levels		
		L1	L2	L3
A	Length of the tube	120	150	180
B	Inner diameter of orifice	5	6.5	8
C	Inner diameter of hot tube	11	14	17
D	Inner diameter of the Nozzle	11	14	17
E	Pressure	2	4	6

As per Taguchi experimental style philosophy a collection of 3 levels allotted to every method parameter has 2 degrees of freedom (DOF). this offers a complete of 10 DOF for 5 method parameters selected during this work. for every trial within the L27 array, the degree of the method parameters area unit indicated in Table.

B). EXPERIMENTAL RESULTS:

The Vortex tube experiments were conducted to study the effect of process parameters over the output response characteristic with the process parameters. The experimental results for temperature are given in Table 2. 27 experiments were conducted using Taguchi experimental design methodology and each experiment was simply repeated two times and the average is calculated for main effect values. In the present study all the designs, plots and analysis have been carried out using Minitab statistical software.

Table2: Taguchi's L27 Standard Orthogonal Array

Trail no	A	B	C	D	E	response temp ^0c	response temp convert to ^0k	response temp ^0k
1	120	5	11	11	2	8	8+273	281
2	120	5	11	11	4	5	5+273	278
3	120	5	11	11	6	3	3+273	276
4	120	6.5	14	14	2	5	5+273	278
5	120	6.5	14	14	4	-1	-1+273	272
6	120	6.5	14	14	6	-3	-3+273	270
7	120	8	17	17	2	8	8+273	281
8	120	8	17	17	4	4	4+273	277
9	120	8	17	17	6	-1	-1+273	272
10	150	6.5	17	11	2	3	3+273	276
11	150	6.5	17	11	4	-2	-2+273	271
12	150	6.5	17	11	6	-5	-5+273	268
13	150	8	11	14	2	7	7+273	280
14	150	8	11	14	4	5	5+273	278
15	150	8	11	14	6	2	2+273	275
16	150	5	14	17	2	8	8+273	281
17	150	5	14	17	4	6	6+273	279
18	150	5	14	17	6	4	4+273	277
19	180	8	14	11	2	8	8+273	281
20	180	8	14	11	4	4	4+273	277
21	180	8	14	11	6	2	2+273	275
22	180	5	17	14	2	10	10+273	283
23	180	5	17	14	4	7	7+273	280
24	180	5	17	14	6	3	3+273	276
25	180	6.5	11	17	2	4	4+273	277
26	180	6.5	11	17	4	2	2+273	275
27	180	6.5	11	17	6	-2	-2+273	271

A-Length of the tube; B-Inner diameter of the orifice; C-inner diameter of the hot tube; D-inner diameter of the nozzle; E-Pressure

VI I. *ANALYSIS AND DISCUSSION OF RESULTS:*

The Vortex tube experiments were conducted by using the parametric approach of the Taguchi's method. The effects of individual vortex tube process parameters, on the selected quality characteristic –temperature, have been discussed in this section. The average value and main effect ratio of the response characteristic for each variable at different levels were calculated from experimental data. The main effects of process variables both for raw data were plotted. The response curves (main effects) are used for examining the parametric effects on the response characteristic. The analysis of variance (ANOVA) of raw data and main effect analysis data is carried out to identify the significant variables and to quantify their effects on the response characteristic. The most favorable values (optimal settings) of process variables in terms of mean response characteristic are established by analyzing the response curves and the ANOVA tables.

A). MAIN EFFECTS PLOT FOR MEANS:

the main effects plot for the means is shown in below. The plots indicate the following figure.

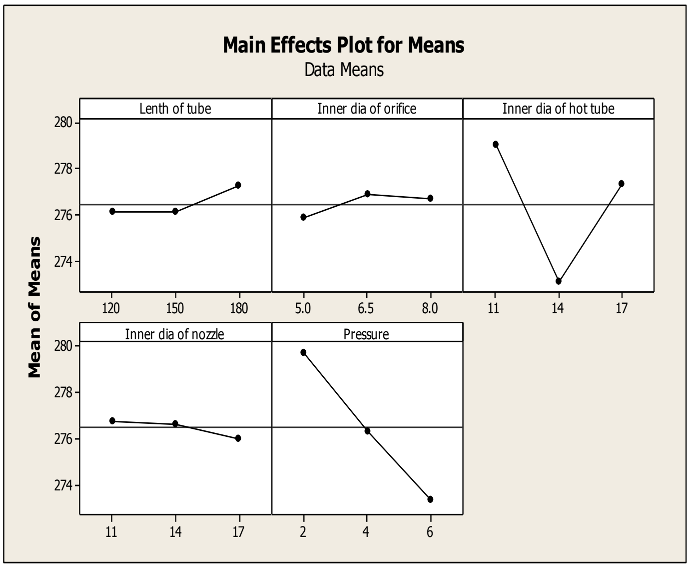

Table:3 .Analysis of Variance for Means

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Lenth of tube	2	7.407	7.407	3.7037	4.00	0.111
Inner dia of orifice	2	4.963	4.963	2.4815	2.68	0.183
Inner dia of hot tube	2	165.852	165.852	82.9259	89.56	0.000
Inner dia of nozzle	2	3.185	3.185	1.5926	1.72	0.289
Pressure	2	187.185	187.185	93.5926	101.08	0.000
Lenth of tube*Pressure	4	2.815	2.815	0.7037	0.76	0.602
Inner dia of orifice*Pressure	4	1.926	1.926	0.4815	0.52	0.729
Inner dia of nozzle*Pressure	4	7.704	7.704	1.9259	2.08	0.248
Residual Error	4	3.704	3.704	0.9259		
Total	26	384.741				

B). *CONFIRMATION EXPERIMENT :*

In order to validate the results obtained, two confirmation experiments were conducted for the response characteristic (Temperature) at optimal levels of the process variables. The average values of the characteristic were obtained. The results are given in Table 1. The values of temperature obtained through confirmation experiments are within the 95% of confirmation experiment of response characteristic. It is to be pointed out that this optimal value is within the specified range of process variables. Any extrapolation should be confirmed through additional experiments,

Table: 4. Confirmation Experiment

Performance measures/Response	Optimal set of parameters	Actual value(°C)
Temperature	A2B1C2D3 E3	-5

VIII .*CONCLUSIONS.*

The effects of the process parameters viz. Length of the tube, Inner diameter of vortex tube, Diameter of orifice, Inner diameter of nozzle and compressed air pressure on response characteristic viz. Temperature was studied. The optimal sets of process parameters were obtained for Temperature using Taguchi's design of experiment methodology. The summary results of predicted optimal values of the responses are given as under:

Table:5.Predicted Optimal Values and Results of Confirmation Experiment

Response	Optimal set of parameters	Predicted value(°C)	Actual value(°C)
Temperature	$A_2B_1C_2D_3E_3$	-4.7	-5

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