Available online at www.elixirpublishers.com (Elixir International Journal)

Mechanical Engineering

Elixir Mech. Engg. 89 (2015) 36747-36750

ISSN: 2229-712X

Optimization of Delrin Vortex Tube Parameters using Taguchi Method

G.Sankaraiah[1,*], C.Umasankar[2] and G.Suresh Kumar[1]

[1]Department of Mechanical Engineering, G.Pulla Reddy Engineering College, Kurnool, Andhra Pradesh, India

[2]Rashriya Sanscrit Vidya Peetha, Tirupati, India.

ARTICLE INFO

Article history:
Received: 23 October 2015;
Received in revised form:
25 November 2015;
Accepted: 02 December 2015;

Keywords
Taguchi Method,
Orthogonal Array,
Vortex Tube,
Composite Material.

ABSTRACT

In this paper Taguchi method is applied for determining the effect of process parameters on vortex tube made of Delrin material. An Experimental work is carried out to analyze the performance of vortex tube with five controllable input parameters namely diameter of the orifices, diameter of the nozzles, length of hot tube, tube diameter and inlet pressure. Cold temperature is considered as output parameter. The various parameters like S/N analysis, ANOVA and Optimal Cold Temperature were carried out in order to determine the effects of process parameters and optimal factor settings.

Introduction

The Vortex Tube can be used in many industrial applications such as cooling equipment of CNC machines, refrigerators, cooling suits, heating process, etc[3]. Since it has no moving parts [1] ; it does not break or wear and therefore it requires little maintenance[1,2]. A Ranque-Hilch vortex tube (RHVT) is a device that splits the compressed air into two streams, one hot and cold temperature streams [3,4]. The schematic diagram of vortex tube is shown in the figure 1.1

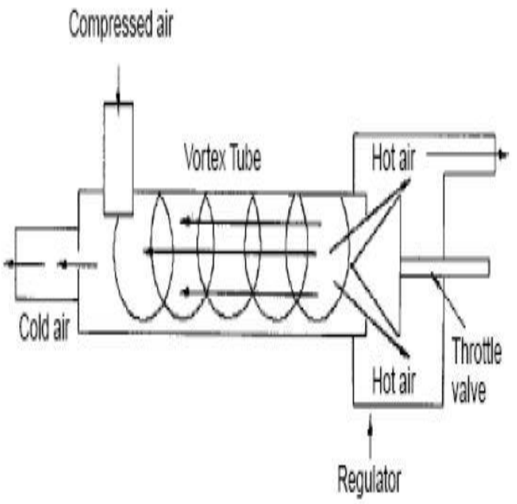

Figure 1. Schematic diagram of Vortex tube

Although vortex tube effect was known for decades, most of the authors studied its effects using metal vortex studied the application of Taguchi method in assessing maximum temperature gradient for the Ranque-Hilch counter flow vortex tube performance . This paper presents experimental results of effect of different parameters influencing vortex tube fabricated with Delrin material.

Experimental setup

The vortex tube assembly is as shown in the figure 2 and the arrangement of the experimental system of a vortex tube is shown in the figure3. The system consists of a vortex tube chamber with the tangential inlet nozzle or vortex generator, cold orifice plate, cone shaped valve, thermocouple, inlet valve and air compressor respectively. During the test, the compressed air was discharged from an air compressor through the pressure gauge with the help of a control valve before entering the RHVT at a given inlet pressure. Inside the RHVT, the air is separated into two streams with low and high temperatures. The cold air leaves the RHVT through the cold orifice plate installed near the inlet nozzles, whereas the hot air escaped at the end of the hot tube equipped with the cone shaped valve. The temperatures are noted by using digital thermometer.

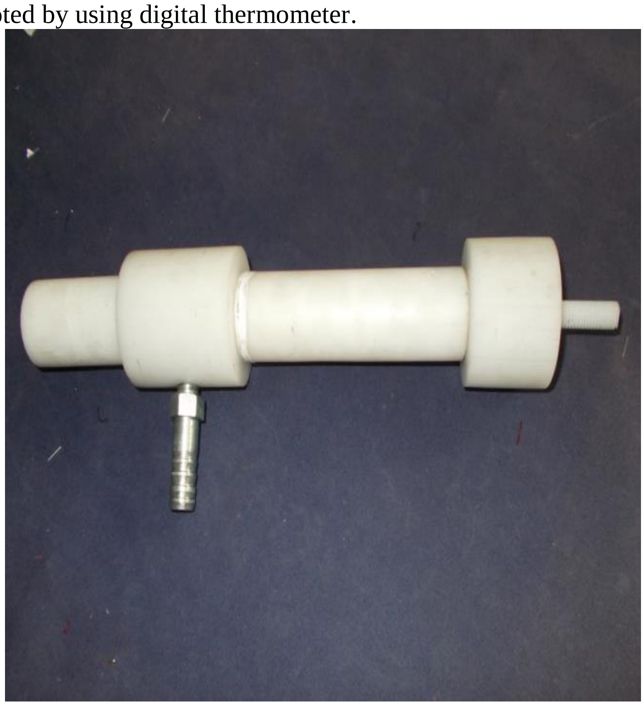

Figure 2. Vortex tube assembly

The aim of the experiment is to study the variation of temperature at cold end with respect to various working and geometrical parameters and determination of its suitability to air conditioning applications and planning experimentation on it.

Tele: +919441020257
E-mail addresses: sankargandla74@gmail.com

Figure 3. Vortex tube experimental setup

The parts i.e., inlet tube, main body (flange), cold tube, hot tube, nozzle, diaphragm and control valve are fitted one by one. The compressor is studied and the Pressures are maintained. The settled vortex tube is placed on the table and the outlet of the compressor is attached to the inlet of the apparatus. First the compressor is maintained at a pressure of 2 bars and the air is allowed to pass through the inlet and we have to wait for 5 minutes. After this the thermometers are placed at both the ends and the readings are noted. The temperature of inlet air is also noted down using a digital thermometer.Then the compressor pressure is increased to 3 bars and the readings are taken in a similar manner. The procedure is followed up to 4 bars. The readings are tabulated as shown. After taking the readings with all the diaphragms, the hot tube is changed which as different Lengths. The experiment is carried out in a similar manner for all hot tubes.

Assumptions

- Mass flow rate of air entering into compressor is equal to mass flow rate of air entering in to the vortex tube maintaining at constant pressure in receiver tank.
- Assuming no losses i.e. inlet mass flow rate of air is equal to the summation of mass flow rate of cold air, and mass flow rate of hot air.
- Constant pressure is maintained in each experimental trail.
- There is no interaction effect of parameters on temperature.
- There are no noise factors present while performing experiment.

Parameter selection and their levels

For the present experimental work the five process parameters each at three levels have been considered. It is desirable to have three minimum levels of process parameters to reflect the true behaviour of output parameter of study. The process parameters are renamed as factors and they are given in the adjacent column. The levels of the individual process parameters are given in Table 1.

Table 1. Process Parameters and their Levels

Factors	*Parameters*	*Levels*		
		L1	*L2*	*L3*
A	Length of the tube	120	150	180
B	Inner diameter of the tube	11	14	17
C	Orifice diameter	5	6.5	8
D	Nozzle diameter	11	14	17
E	Pressure	2	3	4

Experimental results

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

Table 2. Taguchi's L27 Standard Orthogonal Array

Column No.	1	2	3	4	5	Average Response (Temperature °K)	S/N Ratio
Trail No.	A	B	C	D	E		
1	120	11	5	11	2	278.0	-48.8809
2	120	11	5	11	3	270.0	-48.6273
3	120	11	5	11	4	270.0	-48.6273
4	120	14	6.5	14	2	287.0	-49.1576
5	120	14	6.5	14	3	285.5	-49.1121
6	120	14	6.5	14	4	285.0	-49.0969
7	120	17	8	17	2	288.0	-49.1878
8	120	17	8	17	3	288.0	-49.1878
9	120	17	8	17	4	283.0	-49.0357
10	150	11	6.5	17	2	273.0	-48.7233
11	150	11	6.5	17	3	271.0	-48.6594
12	150	11	6.5	17	4	269.0	-48.5950
13	150	14	8	11	2	286.0	-49.1273
14	150	14	8	11	3	283.0	-49.0357
15	150	14	8	11	4	282.0	-49.0050
16	150	17	5	14	2	291.0	-49.2779
17	150	17	5	14	3	289.0	-49.2180
18	150	17	5	14	4	286.0	-49.1273
19	180	11	8	14	2	278.0	-48.8809
20	180	11	8	14	3	277.0	-48.8496
21	180	11	8	14	4	276.0	-48.8182
22	180	14	5	17	2	291.0	-49.2779
23	180	14	5	17	3	287.0	-49.1576
24	180	14	5	17	4	287.0	-49.1576
25	180	17	6.5	11	2	282.0	-49.0050
26	180	17	6.5	11	3	281.0	-48.9741
27	180	17	6.5	11	4	280.0	-48.9432

Analysis 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 –cold temperature, have been studied. The average value and S/N ratio of the response characteristic for each variable at different levels were calculated from experimental data. The response curves (main effects) are used for examining the parametric effects on the response characteristic. The analysis of variance (ANOVA) is carried out to identify the significant variables and to quantify their effects on the response characteristic. The most favourable values (optimal settings) of process variables in terms of mean response characteristic are established by analyzing the response curves and the ANOVA tables.

Main effect plots for means

Main effects plots show how each factor affects the response_characteristic. A main effect is present when each level of the factor affects the characteristic in the same way and the characteristic average is the same across all factor levels. When the line is not horizontal (parallel to the x-axis), then there is a main effect present. Different levels of the factor affect the characteristic differently. The greater the difference in the vertical position of the plotted points (the more the line is not parallel to the X-axis), the greater the magnitude of the main effect.

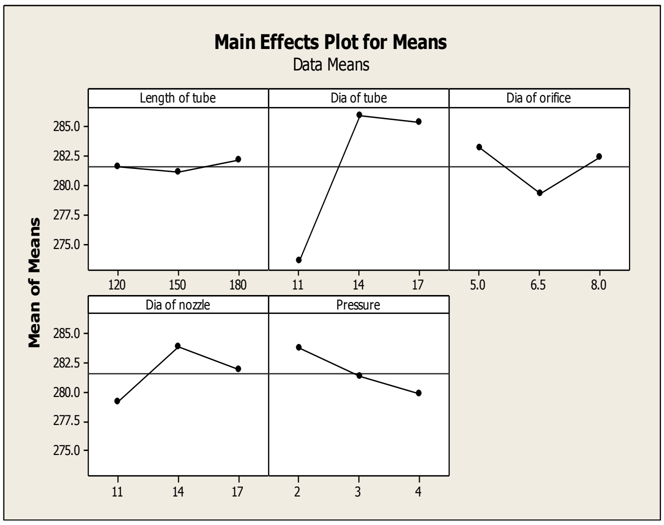

Figure 4. Effects of Process Parameters on Temperature

For the figure 4, the main effects plot for the means is shown. The plots indicate the following:

- Lowest points in the graphs show that the Response (minimum cold temperature) could be got by the optimal factor settings at Pressure=4, Orifice diameter=6.5, Inner diameter of tube=11, Nozzle diameter=11, Length of the tube=150.
- Nozzle diameter has the greatest effect on the response.
- From main effect plots optimal parameters are A2B1C2D1E3.

Table 4. Analysis of Variance for Temperature

Source	DF	Seq SS	Adj ss	adjMS	F	P
Length of tube	2	0.00484	0.00484	0.002421	1.23	0.318
Diameter of tube	2	0.84814	0.84813	0.424070	215.92	0.000
Diameter of orifice	2	0.07295	0.07295	0.036475	18.57	0.000
Diameter of nozzle	2	0.09648	0.09647	0.048239	24.56	0.000
Pressure	2	0.07020	0.07020	0.035102	17.87	0.000
Residual Error	16	0.03142	0.03142	0.001964		
Total	26	1.12404				

DF - degrees of freedom, SS - sum of squares, MS – mean squares(Variance), F-ratio of variance of a source to variance of error, P < 0.05 - determines significance of a factor at 95% confidence level

Table 5. Response Table for signal to noise ratios

Level	*Length of tube*	*Inner dia tube*	*Orifice dia*	*Nozzle dia*	*Pressure*
1	-48.99	-48.74	-49.04	-48.91	-49.06
2	-49.01	-49.13	-48.92	-49.06	-48.98
3	-48.97	-49.11	-49.01	-49.00	-48.93
Delta	0.03	0.39	0.12	0.15	0.12
Rank	5	1	4	2	3

Selection of optimal parameters

In order to study the significance of the process variables towards temperature, analysis of variance (ANOVA) was performed. From Table 4, it is clear that all the process parameters diameter of the tube, orifice diameter, nozzle diameter and pressure except length of the tube, significantly affect both the mean and the variation in the temperature values. The table 5 shows ranks based on delta statistics, which compare the relative magnitude of effects. The delta statistic is the highest minus the lowest average for each factor. Minitab assigns ranks based on delta values; rank 1 to the highest delta value, rank 2 to the second highest, and so on. The ranks indicate the relative importance of each factor to the response. The ranks and the delta values show that Inner diameter of tube have the greatest effect on temperature and is followed by nozzle diameter, pressure, and orifice diameter in that order.

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 6. 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 predicted value is within the specified range of error.

Table 6. Results of Confirmation Experiment

Response	*Optimal set of parameters*	*Predicted value(°C)*	*Actual value(°C)*
Temperature	A2B1C2 D1 E3	266.389	269

Conclusions

In this paper, effects of process parameters in deltrin vortex tube on cooling temperature were investigated through Taguchi method. The experiments were planned as per Taguchi's L27 orthogonal array by considering parameters diameter of the orifices, diameter of the nozzles, length of hot tube, tube diameter and inlet pressure. The important conclusions from this work are summarized as follows.

1. The most significant factor influencing cold temperature is Inner diameter of tube.
2. 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.
3. The optimal sets of process parameters were obtained for Temperature using Taguchi's design of experiment methodology.

Acknowledgment

First author gratefully acknowledges the sponsorship of this work by UGC, New Delhi under Research award scheme 2012-14.

References

[1] Y.T.Wu., Y. Ding. et al , "Modification and experimental research on vortex tube", Elsevier International journal of refrigeration Vol. 30, Pp.1042-1049, 2007.

[2] S.Eiamsa-ardand P.Promonge, "Review of Ranque-Hilch effects in vortex tubes", Renewable and sustainable energy reviews Vol.12, Pp.1822-1842,2007.

[3] Ahmat murat pinar, Onuralp vluer et al , "Optimization of counter flow Ranque-Hilchvortex tube performance using Taguchi method", Elsevier International journal of refrigeration, Vol. 32 ,PP. 1487-1494, 2009.

[4] S.Eimsa-ard and K.Wongcharee.K, Experimental investigation on energy separation in a counter- flow Ranque_Hilch vortex tube : effect of cooling hot tube , Elsevier International communication in heat and mass transfer, Vol.37, Pp.156-162, 2010.

[5] M.S.Phadke, "Quality engineering using robust design", Prentice hall,1989 .

[6] J.R.Philip, "Taguchi techniques for quality engineering", Mcgraw hill book company, 1988.

[7] W.H.Yang and Y.S.Tang , "Design optimization of cutting parameters for turning operations based on the Taguchi method" , Journal material processing technology Vol.84 (1-3), 122-129.

[8] R.K.Roy, " Design of experiments using the Taguchi approach", Wiley-Interscience publications, 2001.

[9] P.K.Singh, R.G. Tathgir, D. Gangacharyulu, and G.S. Grewal. "An experimental performance evaluation of vortex

tube. Journal of Institution of Engineers (India), 84:149–153, Jan. 2004.

[10] Soni Y and W.J. Thomson. Optimal design of the Ranque-Hilsch vortex tube. Trans. SME, J. Heat Transfer, 94(2):316–317, 1975.

[11]]. K.Stephan S. Lin, M. Durst, F.Huang and D. Seher , (), "An investigation of energy separation in a vortex tube". Int. Journal of . Heat & Mass Trans. 26, 341-348, 1983.

[12] O.Hasan, E.Tuncay and V.Ibrahim, "Application of Taguchi optimization technique in detrmining plastic injection molding for a thin-shell part", Materials and Design, Vol.28, Pp:171-178, 2007.

[13] L.Khodorkov, N.V.Poschernev and M.A.Zhidkov, "The vortex tube- a universal device of heating, cooling, cleaning and drying gases and separating gas mixtures", Chemical and Petroleum engineering, Vol.39, Pp.409-415, 2003.

[14] M.H.Saidi and M.S.Valipour, " Experimental modeling of vortex tube refrigerator", Applied thermal engineering, Vol.23, Pp.1971-181, 2003.

[15] A.Manna and B.Bhattacharya, " Investigation for optimal parametric combination for achieving better surface finish during turning of Al/Sic-MMC", International Journal of Advanced manufacturing technology", Vol.23, Pp.658-665, 2004.

[16] S.Basavarajappa, G.Chandramohan and J.P Davim, " Application of taguchi techniques to study dry sliding wear behavior of metal matrix composites", Materials and design, Vol.28, Pp.1393-1398, 2007.