Force Convention Industrial Process Heating using Oven for Buffs Wheels Curing

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Abstract: In this study industrial oven curing process parameters are optimized by using Taguchi method. Process parameters considered for the study are air flow rate, cycle time and temperature. Sisal material valued for cordage use because of its strength, durability, ability to stretch, affinity for certain dyestuffs, and resistance to deterioration in saltwater buffs wheel of circular shape has been used for curing operation. Performance of industrial oven machine by moisture content. In Taguchi method L9 orthogonal array has been selected. The analysis of variance (ANOVA) has been used to determine effect of each parameter on moisture content.

Keywords: Taguchi Method, Signal to Noise (S/N) Ratio, Optimization, Process Parameters, Moisture Content.

I. INTRODUCTION

In recent times, in continuous manufacturing lines, however all processes are linked and the slowest process drives the lead time of the whole manufacturing lines. Usually the cost for replacing equipment is such that this cannot be considered. This is especially the case for products that require thermal treatment (such as curing) that require the use of long continuous ovens. The length of such ovens is decided based on the time that the product requires spending in a specific temperature setting. Obviously, the higher the speed of the line, the longer the oven needs to be for maintaining the temperature above the curing temperature. The performance, though can be increased if the efficiency of the oven is improved. A variety of heat treatment chambers such as furnaces, kilns and ovens are widely used in different industries. Among the numerous heat transfer technologies developed, thermal transfer from hot air nozzles within convection ovens are extensively used, including the glass temper, product Industrial ovens are commonly used in the manufacturing industry for curing, drying or baking. An oven's performance, compared to the best available practice, can decrease over time due to structural/mechanical degradation, technology advancements or changing process requirements. There is potential for functionality improvement, in terms of energy and process performance, in many existing industrial ovens. Heating applications consume almost 1/5 of all industrial energy Micro electro-mechanical systems require performing machining operations with dimensional accuracy in micrometers or nanometers. As technology advances, the need for small size of the components has been increasing with complexity in shapes and sizes, and with reduction in size of the manufacturing machine itself. The aim of improving industrial oven should be to increase product quality, production efficiency and worker safety, as well as to reduce energy consumption and waste. Process variation of operating conditions has a significant impact on product quality, performance, cost, safety and operational efficiency. The cost reduction associated with lean manufacturing is important for businesses in increasingly competitive markets products over the energy consumption, and this prioritization affects how energy reduction is pursued within industry.

II. EXPERIMENTATION

A. Methodology of Experiment

There are several optimization techniques to develop product, process or operation. Various techniques can be applied to optimize curing process. Sometimes different techniques are required integrate to get statistically significant results, which can lead to better conclusions and recommendations. Some extensively used methods in developing a process or a product are Build Test Fix (BTF), Design of Experiment (DOE) and One Variable at a Time (OVAT), BTF is very primitive and unorganized approach. It is iterative method of developing a process focused on improvement from last experiment. DOE is highly efficient method of investigating the effect of parameters as it varies multiple parameters at once. As more parameters are investigated, more number of new combinations is required. DOE cannot control individual parameters and more relies on statistical data. In one variable at a time (OVAT) approach, variation is done with one variable at a time and other parameters are kept constant until the effect of one parameter is studied.

It is highly precise method to study effect of each parameter at different levels. Air flow rate, cycle time and cycle time were identified as most predominant parameters affecting the Industrial oven. Based on the observation, Taguchi method has been used to optimize the process parameters. OVAT analysis has been conducted to find out effective range of parameters for optimization study. L9 orthogonal array (OA) has been selected from available designs. Standard notation for OA is given below

OA = Ln (Xm)

Where n= number of experiments, X= number of levels and m= number of parameters under study. From available designs for 3 levels 3 parameters, OA with least number of experiment required to conduct (L9) has been selected. ANOVA has been conducted to find out contribution of each parameter in the output. Minitab

19 software has been used for analysis.

B. Experimental Machine Selection

Table 1 states the specification of the Industrial oven used in this study. All the experiments were conducted at at SURYA Industries, Plot No. 169, Gut No. 48, Waluj MIDC, Aurangabad, M.S, India.

Make and Model	**Ace E444**
Hertz	60Hz
Maximum Operating Temperature:	260oC
Recirculation Fan Motor Power Range	: 1.5 HP to 20.0 HP
Internal Dimensions Range (W x H x D)	6’x6’x6’ to 12’x12’x30’
External Dimensions Range (W x H x D)	6 x 8’ x 7’ to 14’ x 14’ x 31’

Table 1. Oven Specification.

Figure 1. Industrial Oven Machine

C. Selection of material

Sisal fibers are smooth, straight and fairly coarse and inflexible so the sisal fiber can be long or short. Sisal is valued for cordage use because of its strength, durability, ability to stretch, affinity for certain dyestuffs, and resistance to deterioration in saltwater. Sisal buffs are generally used on hard metals like stainless steel and iron to remove scratches up to 400 grit all Buffing Wheels must be used with polishing compound Chemical composition of Sisal material is shown in Table 2

Composition	Cellulose	Hemi-Cellulose	Lignin	Pectin	Wax
Percentage	67-78 %	10-14.2%	8-11%	10%	2%

Table 2 Chemical Composition of Sisal material.

Figure 2. Sisal material and a test specimen

III. RESULTS AND DISCUSSION

To get complete understanding of effects of input parameters air flow rate, cycle time and temperature on output moisture content, you usually assess signal to noise ratio or main effects plot for means. For this purpose, Minitab 19 statistical software has been used. Modeling of moisture content has been done. ANOVA has been conducted to find out effect of each parameter on the moisture content and linear regression model has been established to predict the values of moisture content.

A. Experimental Result

Table 4 shows the L9 orthogonal array with measurement of moisture content for runs one to nine. It also shows S/N ratio for all nine experiments.

Experiments	Inputs Factors			Output Responses	
Trial No.	**Temperature**	**Air flow rate**	**Cycle time**	**Moisture content**	**S/N Ratio**
1	75	0.037	390	10.15	-20.1293
2	75	0.042	420	10.59	-20.4979
3	75	0.047	450	8.59	-18.6799
4	80	0.037	420	17.02	-24.6192
5	80	0.042	450	16.89	-24.5526
6	80	0.047	390	8.99	-19.0752
7	85	0.037	450	14.18	-23.0335
8	85	0.042	390	10.06	-20.0520
9	85	0.047	420	9.08	-19.1617

Table 3 L9 orthogonal array with response characteristic.

The S/N ratio values are calculated with help of Minitab 19 software. It can be seen that variation in S/N ratio is minimum for all experiment.

B. Main Effects of Moisture Content

Figure 2 shows the main effects plot from S/N ratios.

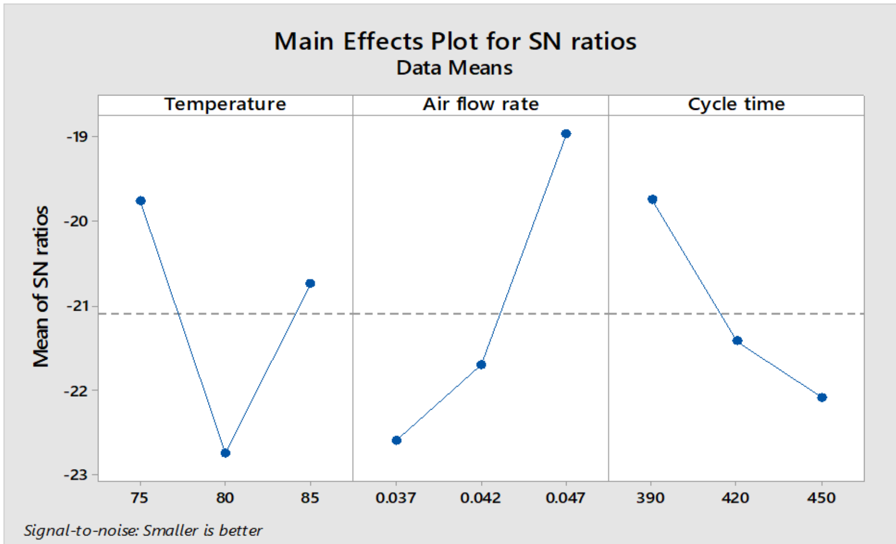

Figure.3.1 Main Effects Plot for S/N Ratio

From main effects plot for S/N ratio, parametric effect on response characteristic i.e. moisture content can be understood. Temperature 75oC at level 1, Air flow rate 0.047 at level 3, Cycle time 390 min at level 1 gives the highest signal to noise ratio values. The levels at which highest S/N ratio obtained from S/N ratio plot taken as optimum levels setting for machine parameters.

C. ANOVA Result

ANOVA, the ratio between the variance of the cutting parameter and the error variance is called Fisher's ratio (F). It is used to determine whether the parameter has a significant effect on the quality characteristic by comparing the F test value of the parameter with the standard F table value at the P significance level. If the F test value is greater than P test the cutting parameter is considered significant. Relevance of the models is tested by analysis of variance (ANOVA). It is a statistical tool for testing the null hypothesis for planned experiments, in which several different variables are studied simultaneously. ANOVA is used to quickly analyze the variances in the experiment using the Fisher test (F test). ANOVA table shown the result of the ANOVA analysis. ANOVA analysis makes it possible to observe that the value of P is less than 0.05 in the three parametric sources. It is therefore clear that temperature, air flow rate and cycle time of the material have an influence on the Sisal material. The last column of cumulative ANOVA shown the percentage of each factor in the total variance that indicates the degree of impact on the outcome. Table 3 shows results obtained from analysis of variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value	% Contribution
Temperature	2	32.427	16.2134	30.98	0.031	35.40
Air flow rate	2	38.743	19.3715	37.01	0.026	42.30
Cycle time	2	19.370	9.6851	18.51	0.051	21.14
Error	2	1.047	0.5233			
Total	8	91.587				

Table 3 ANOVA Result.

It shows that the Temperature (35.40%), the Air flow rate (42.30%) and the Cycle time (21.14%) have major influence on the moisture content. Contribution of Air flow rate (42.30%) is highest among all three parameters hence it is most dominating parameter while cycle is least affecting parameter.

D. Development of Regression Model for moisture content

Regression model has been developed using Minitab software. Substituting the experimental values of the parameters in regression equation, values for moisture content have been predicted for all levels of study parameters. Graphical representation also shows that a predicted and experimental value of moisture content correlates with each other.

Regression Equation –

$$\text{Moisture Content} = -2.8 + 0.133\,[\text{Temp}] - 490\,[\text{Air flow rate}] + 0.0581\,[\text{Cycle time}]$$

Table number 4 gives comparison between experimentally measured and predicted moisture content by developed mathematical equation

Sr. No.	Experimental value	Predicted value	Error %
1	10.15	11.20	9.34
2	10.59	10.49	7.95
3	8.59	9.49	9.48
4	17.02	16.61	2.46
5	16.89	15.40	9.67
6	8.99	8.46	6.26
7	14.18	15.52	8.36
8	10.06	10.58	4.91

9	9.08	9.87	8.04

Table 4 Experimental and Predicted Values of Moisture content

Difference between moisture content values calculated using regression equation and experimental values for each experience found less than 10%. Hence, we can say that the regression equation developed is valid. Figure 3 shows the graphical representation of experimental and values calculated using regression equation.

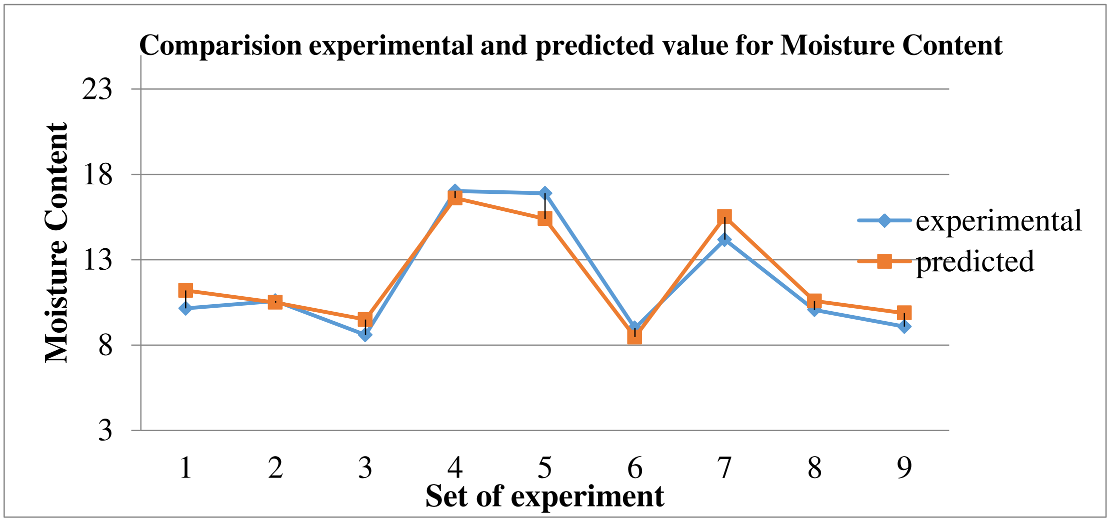

Figure 3 Comparison between Experimental and Predicted value of Moisture content.

E. Confirmation Experiment Result

Table 5 shows the difference between value of moisture content of confirmation experiment and value predicted from regression model developed.

Parameter	Model value	Experimental value	Error %
Moisture Content (%)	7.20	7.86	9.16

Table 5 Confirmation Experiment Result

Confirmation experiment is conducted by keeping parameters at optimum levels suggested by Taguchi method and the moisture content value obtained has been compared with value predicted by the regression model keeping the parameters at same levels. It can be seen that the difference between experimental result and the predicted result is 9.16%. This indicates that the experimental value correlates to the estimated value.

IV. CONCLUSIONS

In this study the influence of process parameters such as temperature, air flow rate, cycle time and their optimization for buffs wheels has been studied by using Taguchi Method. Following conclusions are drawn.

- The optimal solution obtained for moisture content based on the combination of curing oven parameters and their levels is Temp 75 ^{o}C (level 1), Air flow rate 0.047 m^3/s (level 3) and Cycle time 390 min (level 1)
- ANOVA results indicate that air flow rate plays prominent role in determining the moisture content. The contribution of temperature, air flow rate and cycle time to the quality characteristics moisture content is 35.40%, 42.30% and 21.14% respectively.
- ANOVA results indicate that contribution of air flow rate on moisture content is lower followed by cycle time and temperature. Air flow rate is most dominant factor. This may be due to fact that higher the air flow rate, lower will be the moisture content present on buffs wheels
- Value of moisture content is lower obtained in confirmation experiment. Hence, good quality of buffs wheels while curing can be achieved using suggested level of parameters by Taguchi method.
- Values of moisture content calculated using regression model correlates with experimental values with error less than 10%. Hence the model developed is valid and experimental results of moisture content with any combination of curing oven parameters can be estimated within selected levels.

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