Optimization surface roughness parameters for oak color sprayings

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Abstract

This paper presents the optimization condition on oak color spraying. Factors impacted on spraying are controllable and uncontrollable. Controllable factors are a) color viscosity, b) distant between part and nozzle c) nozzle speed, d) Feed rate and e) nozzle pressure. Uncontrollable is temperature (T). The first step of this study finds out the controllable factors, which is the internal factors by using experimental design method. The design of experiment technique (DOE) [3] is used to reduce numbers of experimental, base on standard orthogonal array- table, 5 main factors 2 levels; L_{16} (2^{15}). The experimentation is focus on numbers of defect part. The parameters a) and e) are screened from 5 factors by variant of analysis. It is found that the viscosity and nozzle pressure are significant impact to defect part at 95% confidence ($\alpha = 0.05$). The second step is to study relationship between significant internal factors and temperature, finding out the optimal condition. The results was received from running software are the optimal-condition at viscosity, temperature and nozzle pressure are 10.22 poise 4 bars and 41 degree Celsius respectively. The rejected part is minor 0.0947 and desirability is 1. It means that a number of rejected parts are zero and it is a best case. The adjusted optimize results for the practical work is viscosity; temperature and pressure are 10.5 poise 4 bars and 41 degree Celsius. The rework parts 0.1944 pieces and 0.88 desirability. It can be accepted and this can be practically adjusted.

Keyword: DOE (design of experiment), Taguchi Method

1. Introduction

A shiny and smooth surface is represent the quality of wood furniture. The black walnut color is the popular color and used for a main part of various furniture module. The problems of using unsuitable condition lead to roughness surface and defect products as show in a figure 1.

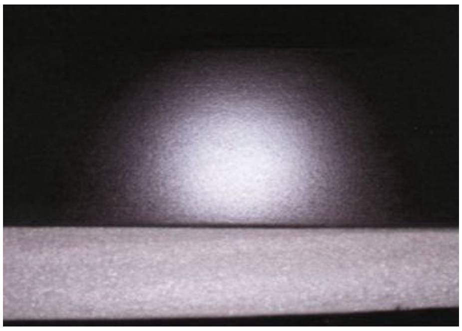


Figure 1 the surface roughness in Oak painting

The furniture module was built up from the semi- finished parts, which are already painted with oak color and it was inspected in each piece in 3 dimensions surface. The quality of product and rejected part was defined by roughness surface. The roughness surface of oak color spraying is occurred from the spraying condition. It is shown in figure 2. The parameters can be classified in to two groups "the controllable factors and uncontrollable factors". A different types of defected parts are shown in fig 2.

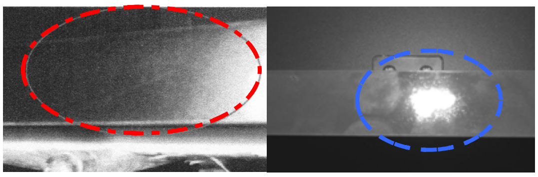


Figure 2 the defected part

The controllable factors are (a) color viscosity (b) distant between part and nozzle (c) nozzle speed (d) Feed rate and (e) nozzle pressure. The uncontrollable is a temperature (T). The parameters: a viscosity of color is defined as concentration of color, a nozzle speed is a velocity of a nozzle, feed rate is a number of parts per minute and nozzle pressure is a pressure in a spraying bottle. In process of oak color spraying, the rework parts are around 30 %. It is made high producing cost. This is the initial point to solve the problems of crude surface for reducing the rejected part and producing cost. In practical, the involve factors are define by controllable (a) color viscosity, b) distant between part and nozzle c) nozzle speed d) feed rate, e) nozzle pressure a-e and uncontrollable factors, temperature (T) that can be done by inspect raw material or setup machine.) The quality control is done by 100% semi-finish parts before assembly to be a product.

2. The evaluation Method

From the control chart of the spraying process, the reject part can be eliminated by adjusting machines for reduce rework parts. The method for solving this problem is used design of experiment (DOE).The efficient method is the Taguchi method, which is reduce time and cost of experimentation by decreasing number of treatment. The plan of experiment is design the matrix experiment, conduct and collects data. A standard orthogonal array is useful. It can be used with multivariable. The standard orthogonal array is presented in table 1.

Table 1 the standard orthogonal array table

Trail	Column no.														
no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2
3	1	1	1	2	2	2	2	1	1	1	1	2	2	2	2
4	1	1	1	2	2	2	2	2	2	2	2	1	1	1	1
5	1	2	2	1	1	2	2	1	1	2	2	1	1	2	2
6	1	2	2	1	1	2	2	2	2	1	1	2	2	1	1
7	1	2	2	2	2	1	1	1	1	2	2	2	2	1	1
8	1	2	2	2	2	1	1	2	2	1	1	1	1	2	2
9	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
10	2	1	2	1	2	1	2	2	1	2	1	2	1	2	1
11	2	1	2	2	1	2	1	1	2	1	2	2	1	2	1
12	2	1	2	2	1	2	1	2	1	2	1	1	2	1	2
13	2	2	1	1	2	2	1	1	2	2	1	1	2	2	1
14	2	2	1	1	2	2	1	2	1	1	2	2	1	1	2
15	2	2	1	2	1	1	2	1	2	2	1	2	1	1	2
16	2	2	1	2	1	1	2	2	1	1	2	1	2	2	1

The standard orthogonal array table consists of sets of experiment. In this paper used orthogonal array base L_{16} 2^{15} (16 treatments), 15 maximum factors, 5 mains controllable factors, 10 combination parameters. The variant analysis, ANOVA analysis are used to screen the influent controllable factors. Uncontrollable and controllable parameters are cross by optimization technique, determining the suitable condition for smoothly and shiny painting. The results can be verified from additive model.

3. Experimental Data

The experimentation is focus on defect parts. The maximum and minimum viscosity is around 10-12 poise and pressure range 2 to 4 bars. Data collection is done by varies viscosities from 10-12 poise and pressure range 2- 4 bars as a pilot testing. The graph below is plot to analyze relationship between the controllable parameters that impact to color spraying as show in figure 3. As you seen in the picture A and E. There are deviated from means value that means factor a and e are impacted to oak color spraying process. The picture B, C and D, the distributetion of data approach normal distribution (dot line).

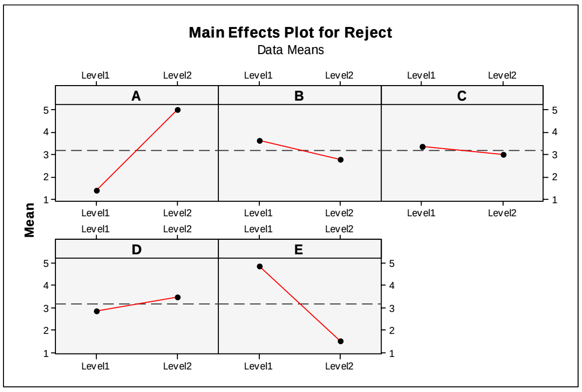


Figure 3 The main effect plot for reject fitted means

The interaction plot of controllable factors a-e in picture below. There are 2 factors (a) viscosity & (e) nozzle pressure has significant impact to oak color spraying as show in figure 4.

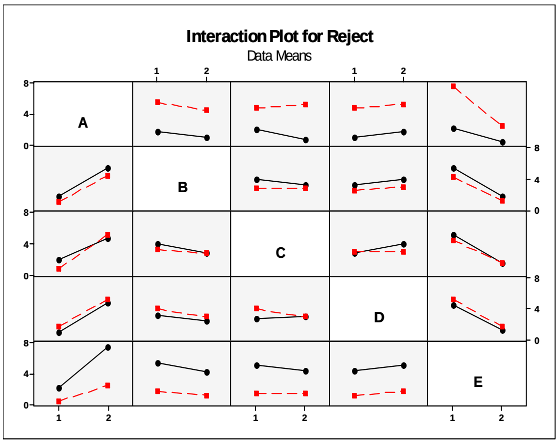


Figure 4 The interaction Plot for reject data means

In room temperature, the oak color can be dried, but temperature is influent to color spraying environment, drying time. The collected data from control chart shown a maximum and minimum temperature range around 37-41 degree Celsius

4. Evaluation Results

The screening for controllable factor is given 2 significant controllable factors (color viscosity and nozzle pressure). The cross of desired controllable factors and uncontrollable factor T are set up as a model. The suitable parameters for oak spraying run by statistical software are shows in figure 5. The condition at viscosity 10.22 poise, nozzle pressure 4 bars and temperature 41 degree Celsius were received.

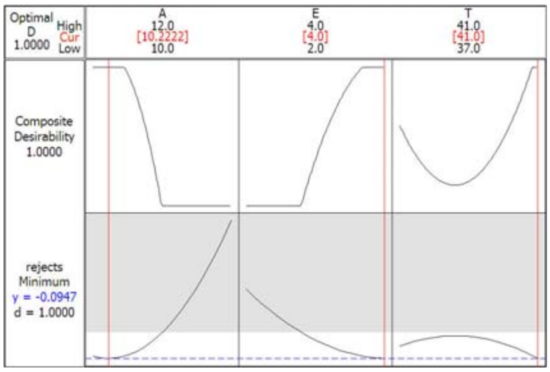


Figure 5 The optimal point for suitable condition

The adjust results have optimize point at viscosity 10.5 poise, nozzle pressure 4 bars and temperature at 41 degree Celsius. This is possible for tuning the machines in practical and it is still received the good results, therefore it is less defected product. The defected parts(y) can be accepted as show in figure 6.

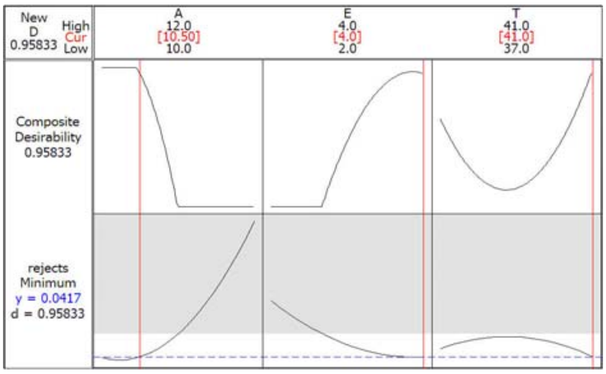
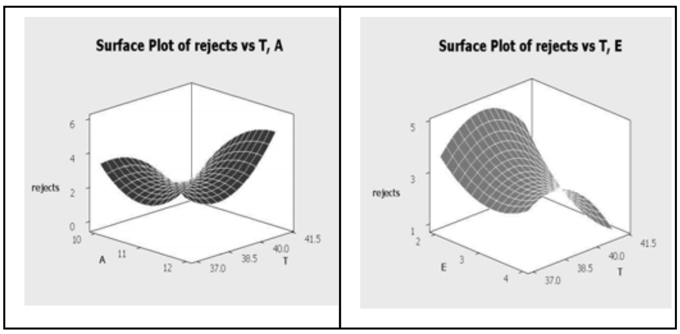


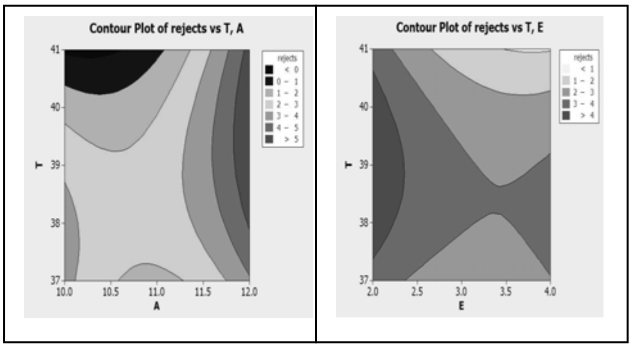
Figure 6 The adjust optimal point for suitable condition



(a) (b)

Figure 7 The surface response
(a) T and A
(b) T and E

The response surface plot of are shown in figure 7a, 7b. It is presented a relationship between parameters. In figure 7a temperature and color viscosity and rejected parts in 3 dimensions. Figure 7b. the temperature and color nozzle pressure and rejected parts are plot in 3 dimensions, presented the correlation of 3 parameters



(a) (b)

Figure 8 the contour plot of rejected part
(a) the contour plot T and A
(b) the contour plot T and E

The contour plot is shown in figure 8a, 8b. It is presented the area of rejected part. Figure 8a shows relationship of temperature and color viscosity. A pale color was found that there are less rejected part. The more defected part is presented degree dark color; for example the black color area, there are 5 defected parts. For figure 8b shows relationship of temperature and nozzle pressure. The area that represented the defected part is done in the same style.

The optimizations results in table 3, shows the rejected part at various temperatures from 37-41 degree Celsius by fixed constant color viscosity and nozzle pressure.
The adjusted optimal condition, which is received from turning machine and fixed the color viscosity at 10.5 poise. The results are compared with the results run from statistics software in the same table. (Table 3)

Table 3.compaired rejected parts at various temperatures.

viscosity (A) poise	Pressure (E) bar	Temperature (T) C	Reject (Rework)	Desirability (D)
10.2222	4	37	0.4239	0.5761
		38	0.7942	0.2057
		39	0.8313	0.1487
		40	0.5350	0.4650
		41	-0.0947	1.0000
10.5	4	37	0.3756	0.6250
		38	0.7917	0.2083
		39	0.8750	0.1250
		40	0.6250	0.3750
		41	0.0417	0.9583

As seen in the table 3, at T equal to 37 degree, viscosity 10.22 poise and pressure 4 bars, the desirability is 0.5761 and the reject part value is 0.4239, compared with T at 41 degree, viscosity 10.22 poise and nozzle pressure 4 bars and the desirability is 1, the reject part value is minus 0.0947.

In practical, the desirability should approach to 1. It means that it is no rejected parts or less rejected part, so the more desirable value close to 1,the more rejected part are less. In adjusted condition case, T equal to 41degree, viscosity was set up equal to 10.5 poise and nozzle pressure 4 bars, the reject part value was given at 0.0417 and the desirability is 0.958, compared with T at 41 degree, viscosity 10.22 poise and nozzle pressure 4 bars the reject part value is minus 0.0947 It can be acceptable for this condition.

$$Reject\ (y) = -1.36 + 1.5(A) - 0.833(E) - 0.25(T) \quad \text{eq (1)}$$

Because of it is easy to control and turning the machine. Both of conditions can be used, but the suitable condition is the optimal condition in practical. The study of the relationship between the uncontrollable and controllable parameters is done but using the regression analysis. The results are given the mathematics equation (1) as the additive model. The regression coefficient is -1.36 and R square 58.3 %, R square (adjust) 33.2 %, which are run from statistics software shows in table 3.

Table 3. The regression results

Regression Analysis: rejects versus A, E, T
The regression equation is
rejects = - 1.4+1.50 (A) -0.833 (E) -0.250(T)

Predictor	Coef	SE Coef	T	P
Constant	-1.36	15.29	-0.09	0.933
A	1.5000	0.6763	2.22	0.077
E	-0.8333	0.6763	-1.23	0.273
T	-0.2500	0.3382	-0.74	0.493

S = 1.65664
R-Sq = 58.3% R-Sq(adj) = 33.2%
Analysis of Variance

Source	DF	SS	MS	F	P
Regression	3	19.167	6.389	2.33	0.192
Residual Error	5	13.722	2.744		
Total	8	32.889			

Source DF Seq SS
A 1 13.500 E 1 4.167 T 1 1.500

5. Conclusion

The optimization surface roughness parameters for oak color sprayings are the condition that applied in the process to produce the oak color part and the parts are zero or less defect. The optimal parameter is given a suitable condition to provide the high quality product. The parameters involves in process are controllable and uncontrollable. Controllable factors are a) color viscosity, b) distant between part and nozzle c) nozzle speed, d) Feed rate and e) nozzle pressure. Uncontrollable is temperature (T). The parameters that directly impacted in process of oak spraying are a) color viscosity and e) nozzle pressure, uncontrollable is temperature (T). The color viscosity is involved with the concentration of color. The nozzle pressure is effect to the drop of solution. Temperature (T) is influent with the dryness and time of dryness. The optimal solution is 41degree; viscosity 10.5 poise and nozzle pressure 4 bars.

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