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Research Paper

Determination of Combination of Optimal Factor Level in Improvement and Uniform Effort of Product Quality Using Taguchi Method

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Abstract

The quality engineering including all of quality control activity in every phase from research and product development, production process planning and the consumer's satisfaction. In the taguchi method used a matrix called orthogonal array located in the level combination election from the variable's input for every experiment's. The experiment result of taguchi method find level combination from the most infivential factor's in decorated ceramic quality are: the mixture composition of raw material;s (level 2), the comparison consist from kaolin = 10 ; felspar = 10 : tanah pucung = 3 ; water glass = 0.25 ; boor clay = 1.25; the composition of dye (level) the comparison cousist from : cobalt = 1 and tanah pucung = 5; the mold sfape (level 2) the kind it's fave a long neck. Besides from the experiment result find the prediction of defect persentase based on total average defect is 6.78 for every burning but based on signal to noise is less or niore 6.619% for every burning.

Keywords: *Quality Engineering, Taguchi Method, ANOVA*

1. Introduction

Quality problem is the most urgent thing[1], [2] on the products produced by ceramic ornamental industry centre, where not all products produced by each home industry have the same quality and often not in accordance with the specifications desired by consumers so that quality is a key factor to be considered in developing an industrial centers[3], [4].
Fortunately in our country there are still many Small and Medium Industries, because Small and Medium Industries can still survive so that a little more can help sustain our economy despite the economic crisis is being hit [5], [6]. This proves that the populist economy may be more appropriately applied in Indonesia, so the direction of economic policy should be in favor of Small and Medium Industry in a way more empower its existence[7], [8].
One way to empower SMEs can be established associations, cooperatives, or industrial centers that can be enabled to coordinate similar Small and Medium Industries in making business networks to further strengthen the existence of Small and Medium Industries. Besides, it is also necessary to improve the quality of products produced by Small and Medium Industries in order to be able to compete in local and international markets and user satisfaction can be improved[9].

Formulation of the problem

1. What factors can be controlled that affect the quality of ornamental ceramics?
2. What is the optimal combination of each influencing factor?
3. How much contribution each influencing factor has on the quality of ceramics.

Research Purposes

1. Knowing the factors that can be controlled along with the levels that affect the quality of the product.
2. Determine the optimal combination of factors and levels that affect quality.
3. Knowing the factors that have the most influence on the quality of ornamental ceramics
4. Uniform product quality at ceramic ornamental industry centre.

Understanding Quality Engineering

Quality engineering can be interpreted as a measurement process undertaken during product/process design. Quality engineering encompasses all quality control activities in every phase of product research and development, production process design and customer satisfaction[10][11].
Engineering quality is divided into two parts which is engineering to identify sources of variation and determine optimal design and process. Engineering quality off-line is divided into 3 (three) stages[12]–[14]:

Phase I Concept Design

It deals with generating ideas in product design and development activities, where the idea is from consumer desires. Model or method used: QFD, Dynamic Signal-to-Noise Optimization, Design of Experiments and others.

Phase II Parameter Design

Serves to optimize the level of the controlling factor against the effects caused by other factors so that the product generated tough to noise. This stage is called Robust Design. The models or methods used include: Engineering Analysis and your Dynamic Static Signal-to-Noise Optimization.

Phase III of Tolerance Design

Serves to balance the cost and quality of a product. Model or method used: Quality Loss Function, Analysis of Variance (ANOVA) and Experiment Design.

Quality Engineering On-Line

Engineering activities to observe and control the quality of each production process directly aimed at keeping the cost of production low and can directly improve product quality. Some models are used in performing on-line quality engineering: Statistical Process Control, Static Signal-to-Noise Ratio, and Loss Function-Based Process Control.

Understanding Quality According to Taguchi

Taguchi method was introduced by Dr. Genichi Taguchi (1940) which is a new methodology in the field of engineering that aims to improve the quality of products and processes and can reduce costs and resources to a minimum. The target of Taguchi method is to make the product robust to noise, because it is often referred to as Robust Design[15][16].

A. Signal Ratio Against Noise (S/N)

Taguchi introduced the S/N ratio approach to examine the effect of noise factors on the variations that arise. The type of S/N ratio depends on the desired characteristics [17], namely: Smaller-the-Better (STB): the lower the value, the better the quality. The S/N values for STB characteristic types are:

$$S/N_{\,STB} = -10\log\left[1/n\sum_{i=n}^{n} y_1^{\,2}\right]$$

Where :
n = number of tests in the experiment (trial)
Larger-the-Better (LTB): the greater the value, the better the quality. The S/N values for the types of LTB characteristics are:

$$S/N_{\,LTB} = -\log\left[1/n\sum_{i=1}^{n} 1/y_1^{\,2}\right]$$

Nominal-the-Better (NTB): set a certain nominal value, if the value is closer to a certain nominal value then the quality is better. S / N value for NTB characteristic type:

S/N NTB = - 10 log Ve (for variance only)

$$S/N_{\,NTB} = -10\log\left[\frac{V_m - V_e}{r\,.\,V_e}\right]$$

(for average and variance)

B. Controlled Factors and Noise Factors

Taguchi develops design and product/process development factors into two groups: controlled factors and noise factors. Controlled factors are factors that are established (or controlled) by the manufacturer during the design stage of the product/process and can't be changed by the consumer. While the noise factor is a factor that can not be controlled directly by the manufacturer [18][17].

C. Design of the Taguchi Experiment

The experimental design is a simultaneous evaluation of two or more factors (parameters) on the ability to influence the mean or variability of combined results from certain product or process characteristics[19], [20]. There are several steps that Taguchi proposes to conduct a systematic experiment:

1) State the problem and determine the purpose of the Study
2) Determine the measurement method
3) Identification of Tractors
4) Separate the control factor and noise factor
5) Determine the level of each factor
6) Choose Orthogonal Array
7) Conduct experiments and analyze results with ANOVA (Analysis of Variance)
8) Interpretation of resultan
9) Selection of factor level for optimal conditions
10) Estimated average process at optimal condition

Determination of Factor, Level and Orthogonal Array

Factors that affect the quality there are seven factors that influence. While to set the levels of each factor then taken from a specification that is widely used by ornamental ceramic manufacturers in the industrial centers are used as research objects. The result of leveling for each factor is:

Table.1: Factor A Composition Glasir

	Level 1	Level 2
Kaolin	1	1
Felspar	9	12
Powder	0.3	0.5
Kalsium	1	1

Table.2: Factor B Type of fuel

Level 1	Level 2
Solar	Kerosene

Table.3: Factor C Mold form

Level 1	Level 2
Short Neck	Long neck

Table.4: Factor D Fire Stove

Level 1	Level 2
Kiln/kontiny (push)	Horizontal (stom)

Table.5: Factor E Composition of Dyes

	Level 1	Level 2
Cobalt	1	1
Pucung Soil	5	8

Table.6: Factor Raw Materials mix

	Level 1	Level 2
Kaolin	10	10
Felspar	10	10
Pucung Soil	5	3
Water glass	0.5	0.25
Boor clay	0.75	1.25

Table.7: Factor G : Drying Method

Level 1	Level 2
Natural	Artificial

The total free degrees in the study were 7 x (2 - 1) = 7, so the orthogonal array used was L8 (27).

Experiment Results

Once the orthogonal array design is set, experiments are performed. Experiments were conducted 5 times in different places/producers in the ceramics industry center.
The summary of the experimental results can be seen in Table 9.

Table.8: L8 OA Experimental Design (2^7)

Exp	Column/Factor							Number of Burning	Percentage of Defects
	A	B	C	D	E	F	G		
1	1	1	1	1	1	1	1		
2	1	1	1	2	2	2	2		
3	1	2	2	1	1	2	2		
4	1	2	2	2	2	1	1		
5	2	1	2	1	2	1	2		
6	2	1	2	2	1	2	1		
7	2	2	1	1	2	2	1		
8	2	2	1	2	1	1	2		

Table.9: Summary of Experimental Results

Exp	Experiment Results (%)					Average	S/N
	Repl.1	Repl. 2	Repl. 3	Repl. 4	Repl. 5	Replication	(μ)
1	10.24%	10.14%	10.06%	10.15%	10.25%	10.17%	-20.1449
2	7.86%	7.76%	7.73%	7.81%	7.78%	7.79%	-17.8287
3	6.48%	6.63%	6.46%	6.52%	6.55%	6.53%	-16.296
4	10.43%	10.24%	10.18%	10.22%	10.44%	10.30%	-20.2589
5	10.75%	10.25%	10.58%	10.73%	10.67%	10.60%	-20.5041
6	6.91%	6.89%	7.24%	6.86%	7.25%	7.03%	-16.9418
7	8.18%	8.13%	7.90%	8.14%	8.12%	8.09%	-18.1639
8	9.87%	10.25%	10.06%	9.86%	10.24%	10.06%	-20.0497

By taking the 5% target assumption, the anova table can be created with the help of the mintab software with the following results table 10.

Optimal level combinations from the experimental results we can know the response of each factor as follows table 11. Average prediction percentage of optimal defect from the result of the optimum combination of factors f2, e1, c2 can be calculated the average prediction percentage of defects that can actually be achieved are:

Table.10: ANOVA for defective contributions

Source	Pool	DF	SS	MS	F count	SS'	p (%)
A		1	0.6126	0.6126	30.766	0.5927	0.63
B		1	0.2265	0.2265	11.3761	0.2066	0.22
C		1	1.7016	1.7016	85.4611	1.6817	1.78
D	Y	1	0.0276	0.0276			
E		1	5.6175	5.6175	282.1394	5.5976	5.93
F		1	85.2932	85.2932	4,283.86	85.2733	90.38
G		1	0.2449	0.2449	12.3012	0.225	0.24
e1							
e2	Y	32	0.6295	0.0197			
(e)		33	0.657	0.0199		0.7765	0.82
Total		39	94.3533	2.4193			

Table.11: Response of the effect of factors on the average percentage of defects

	Factor						
	A	B	C	D	E	F	G
Level 1	8.6965	8.8955	9.0265	8.8465	**8.4455**	10.2805	8.8985
Level 2	8.9440	8.7450	**8.6140**	8.7940	9.1950	**7.3600**	8.7450
Difference	0.2475	0.1505	0.4125	0.0525	0.7495	2.9205	0.1535
Rank.	4	6	**3**	7	**2**	**1**	5

Based on the defect percentage variability (S/N):

a. Analysis of variance on S/N
   By taking the 5% target assumption, the anova table can be created with the help of minitab software with the results seen in table 5.
b. Optimal level combinations
   From the experimental results can be known the response of each factor can be seen in table 12.
c. S/N prediction is optimal
   From the optimal combination of factors F2E1C2 can be calculated the average prediction percentage defects that can actually be achieved.

Table.12: Anova S/Nn for Factor Contribution to the Percentage of Defects

Source	Pool	DF	SS	MS	F Count	SS'	Contribution (%)
A		1	0.1599	0.1599	1,444.75	0.1598	0.82
B		1	0.053	0.053	478.5145	0.0529	0.27
C		1	0.5975	0.5975	5,397.56	0.5974	3.07
D	**Y**	**1**	**0.0001**	**0.0001**			
E		1	1.3804	1.3804	12,469.60	1.3803	7.09
F		1	17.1913	17.1913	155,291.42	17.1912	88.3
G		1	0.0863	0.0863	779.9158	0.0862	0.44
e1							
e2							
(e)		1	0.0001	0.0001		0.0008	0
Total		7	19.4687	2.7812			

Table.13: Responses of Factors Influenced By S/N

	FACTOR						
	A	B	C	D	E	F	G
Level 1	-18.6321	-18.8549	-19.0468	-18.7772	**-18.3581**	-20.2394	-18.8774
Level 2	-18.9149	-19.0468	**-18.5002**	-18.7698	-19.1889	**-17.3076**	-18.6696
Difference	0,2828	0.1919	0.5466	0.0074	0.8308	2.9318	0.2078
Rank	4	6	**3**	7	**2**	**1**	5

2. Analysis and Interpretation

Analysis and Interpretation of Taguchi Method based on result of data processing. The analysis included:

a. ANOVA to see the effect of different status factor levels on the occurrence of defects
b. Percentage of contributions that indicate the contribution of factors to the occurrence of defects
c. Combination factor and optimal level
d. The confidence interval for influencing factors.

The analysis was performed on the average percentage of defects and based on the percentage of defect variables.

A. Based on the average percentage of defects

From ANOVA it is known that level differences in factor D have no effect on percentage of defects. While the factors that have the largest contribution percentage respectively are the factors F, E and C with the combination of the optimal factor level which gives the average percentage of the smallest defect is A1B2C2E1F2G1. If Using Combination factor level above then it can be predicted that the average percentage of defect that happened at each burning is 6.7791% with defect interval between 6.66% s/d 6.9%.

B. Based on variability percentage defects

From ANOVA it is known that level differences in factor D have no effect on percentage of defects. While the factors that have the largest contribution percentage respectively are the factors F, E and C with a combination of optimum factor level that gives the average percentage of the smallest defect is A1B1C2E1F2G1.

From the results of the study also can be predicted that the average percentage of defects that occur in each burning is 6.189% with intervals between 6.6178% s/d 6.62%.

3. Conclusion

Factors affecting the quality of decorative ceramic products in the production process can be controlled are: Glaze composition, fuel type, mold shape, fireplace type, dye composition, raw material mixture composition, and drying method. Based on its contribution, the most influential factors according to the Taguchi experiment are: the composition of the mixture of raw materials, the composition of the dye, and the shape of the mold.

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