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Improving The Quality Of Ceramic Products Through The Application Of The Taguchi Multi Response Method To Increase The Competitiveness Of Ceramic Ukm In The Global Era (Case Study At The Kasongan Ceramics Ukm Center, Bantul, Diy)

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Abstract

Kasongan Ceramic UKM Center is an association of UKM which makes goods made from clay. Kasongan Ceramic UKM Center, located in Bantul Regency, DIY. The problem that is often experienced by Kasongan Ceramics Center is that products that are often cracked, warped, and easily brittle. The total production of Kasongan UKM Center from September 2019 to February 2020 was 32,256 units, with the number of defective products amounting to 3,873 or 12% of the total production. Based on the studies that have been carried out, it can be concluded that the crack, warping, and brittle defects that occur are caused by the lack of maximum flexural strength and the high percentage of dry shrinkage in the ceramic products produced. To maximize the flexural strength and minimize the percentage of dry shrinkage in the resulting ceramic products, the optimal ceramic manufacturing process parameters will be determined using the Taguchi multi-response method. To maximize the flexural strength and minimize the percentage of dry shrinkage in the process of making ceramics using the Taguchi multi-response method, it is necessary to carry out an experimental design. The first thing to do is to determine the controlled factors and levels in the ceramic manufacturing process that affect the flexural strength and dry shrinkage of ceramics. After that determine a suitable orthogonal array and perform experiments based on the specified orthogonal array. The experimental results will be tested for flexural strength and dry shrinkage percentage in the laboratory. The resulting flexural strength and dry shrinkage percentage data will be processed to determine the optimal ceramic manufacturing process parameters that maximize the flexural strength and minimize the percentage of ceramic dry shrinkage. Based on the data processing carried out, it is found that the optimal ceramic-making process parameters at the Kasongan Ceramics UKM Center that maximize the flexural strength and minimize the percentage of dry ceramic shrinkage are 2 parts Godean soil composition, 1 part kasongan soil composition, 1 part sand composition, and combustion using a tub open.

Keyword: Taguchi multi-response method, flexural strength, dry shrinkage

I. INTRODUCTION

I.1. Background of the problem

Kasongan Ceramic UKM Center is an association of UKM which makes goods made from clay. Kasongan Ceramic UKM Center, located in Bantul Regency, DIY. The problem that is often experienced by the Kasongan Ceramics UKM Center is that products that are often cracked, curved, and are easily brittle. The total production of Kasongan UKM Center from September 2019 to February 2020 was 32,256 units, with the number of defective products amounting to 3,873 or 12% of the total production. Based on the brainstorming with the management of the Kasongan Ceramics UKM Center, literature studies conducted, and laboratory tests, it can be concluded that the crack, curved, and brittle defects that occur are caused by the lack of maximum flexural strength and the high percentage of dry shrinkage in ceramic products produced by the center.

This research will solve the problems that occur at the Kasongan Ceramic UKM Center by improving the process of making ceramics so that the resulting product has the maximum flexural strength and a minimum percentage of dry shrinkage. To improve the process of making ceramics at the Kasongan Ceramic UKM Center, it will be carried out using an experimental design. Through an experimental design, optimal ceramic manufacturing process parameters will be generated so that the resulting ceramic has maximum flexural strength and a minimum percentage of dry shrinkage.

The experimental design used in this study used the Taguchi multi-response method, said to be the multi-response Taguchi method because the responses studied were more than one or two, namely the flexural strength and dry shrinkage of ceramics. Basically, the Taguchi method can only be used for one response optimization. In this study, in order to optimize the two responses under study, the Taguchi method will be combined with the Multiple Response Signal to Noise ratio (MRSN) method to obtain a trade-off or compromise solution for the two responses studied.

I.2. Formulation of the problem

Based on the description of the background of the problem above, the problem raised in this study is how to determine the optimal process parameters for the manufacture of ceramic products, so that the resulting ceramic products have the maximum flexural strength and minimum dry shrinkage percentage, in order to increase the competitiveness of Kasongan Ceramic UKM Center in the global era?

I.3. Research purposes

The purpose of this research is to determine the optimal process parameters for the manufacture of ceramic products, so that the resulting ceramic products have maximum flexural strength and a minimum percentage of dry shrinkage, using the Taguchi multi-response method.

II. LITERATURE REVIEW

II.1. Taguchi Method

The Taguchi method was coined by Dr. Genichi Taguchi in 1949 when he got an assignment to repair the telecommunications system in Japan. This method is a new methodology in engineering that aims to improve the quality of products and processes and to reduce costs and resources to a minimum. The goal of the Taguchi method is to make the product robust against noise factors because it is often referred to as robust design.

II.2.Taguchi Multi Respone

Taguchi can be divided into two, namely Taguchi single response and Taguchi multiresponse. Taguchi single response only has one response variable so that the optimal combination of these response variables is immediately obtained. Taguchi multiresponse has more than one response variable (at least two response variables), and each response variable has a different combination of factors so that further treatment is needed to obtain the optimal combination of factors to improve the quality of each response variable. Two methods that can be used to solve the Taguchi multiresponse problem are the MRSN (Multi Response Signal to Noise) and TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method to determine optimal conditions at the parameter design stage (Tong and Chao, 1997).

III. RESEARCH METHODOLOGY

The research steps taken can be seen in the following research framework.

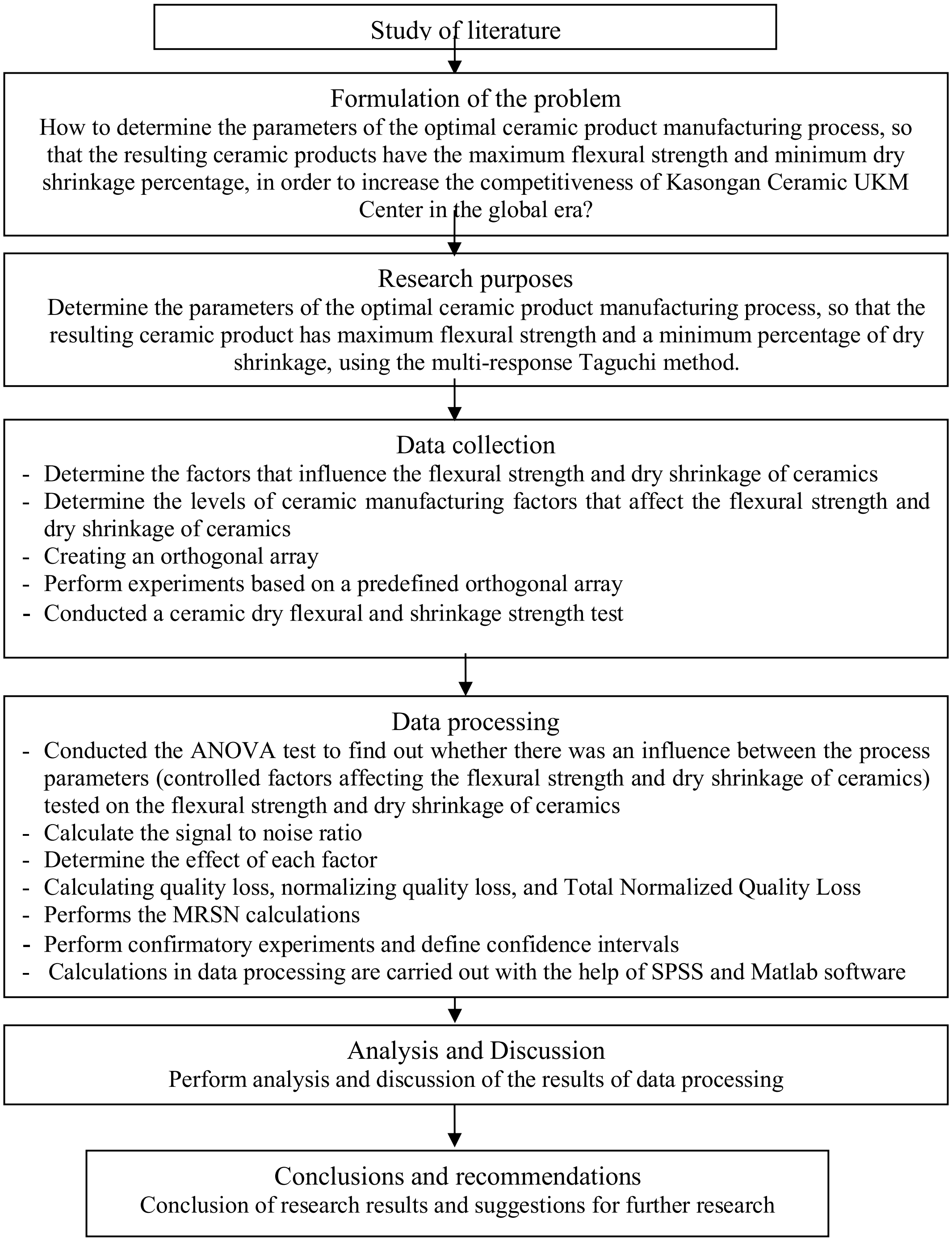

Figure 1. Research Framework

IV.F INDING AND DISCUSSION

IV.1. Data collection

1) Determination of influencing factors and their levels

The factors that affect the bending strength and dry shrinkage of ceramics can be seen in the following table.

Table 1 Controllable factors

Symbol	Control Factor	Level 1	Level 2
A	Composition of Godean Clay	2 parts	3 parts
B	Composition of Kasongan Clay	1 part	3 parts
C	Composition of Sand	0,5 parts	1 part
D	Burning	Open tub	Close tub

Table 2 Uncontrollable factors

Symbol	Uncontrollable factors	Level 1	Level 2
E	Temperature / Air Temperature	Cold	Hot

2) Determination of the orthogonal array

The orthogonal array is determined based on the number of factors and factor levels involved in the experiment. This experiment involves four controllable factors and one uncontrollable factor (noise), each of which consists of two levels so that the inner array in this experiment is L_8 (2^7) and the outer array is L_4 (2^3).

3) Experimental results

The results of the experiments that have been carried out can be seen in the following table.

Table 3.The experimental results of the flexural strength test of ceramic bodies

					Outer Array							
				E	1		2		1		2	
	Inner Array											
Trial No	A	B	C	D	Experimental Data (N/mm^2)							
	1	2	3	4	Y_1		Y_2		Y_3		Y_4	
1	1	1	1	1	24,4	21,7	19,0	24,4	19,4	19,4	18,7	19,0
2	1	1	2	2	19,0	18,7	18,7	19,0	24,4	19,0	17,2	18,7
3	1	2	1	2	19,8	19,8	21,7	18,7	23,0	24,4	21,7	21,7
4	1	2	2	1	23,0	24,4	23,0	17,2	19,4	19,0	18,7	23,0
5	2	1	1	1	19,4	23,0	23,0	21,7	21,7	19,8	23,0	19,0
6	2	1	2	2	28,8	19,4	22,4	18,7	21,6	23,0	28,8	18,7
7	2	2	1	2	21,7	21,7	19,8	23,0	24,4	19,4	19,4	21,7
8	2	2	2	1	19,0	21,6	21,6	28,8	19,0	24,4	19,0	23,0

Table 4.The experimental results of ceramic body dry shrinkage test

					Outer Array							
				E	1		2		1		2	
	Inner Array											
Trial No	A	B	C	D	Experimental Data (%)							
	1	2	3	4	Y_1		Y_2		Y_3		Y_4	
1	1	1	1	1	5	6	6	5	6	5	5	5
2	1	1	2	2	3	3	4	3	5	4	6	3
3	1	2	1	2	6	6	6	7	6	5	4	6
4	1	2	2	1	6	5	6	5	4	6	4	4
5	2	1	1	1	5	5	5	5	5	4	5	4
6	2	1	2	2	2	2	2	2	3	2	2	2
7	2	2	1	2	6	4	4	3	4	4	3	3
8	2	2	2	1	5	5	4	4	5	4	5	5

IV.2. Data processing

IV.2.1. ANOVA (*Analysis of Variance)* calculation

The calculation of ANOVA of flexural strength and dry shrinkage of ceramics is used to estimate the effect of each control factor on the observed characteristics. The following is a table of the ANOVA calculation results.

Table 5. Results of the ANOVA calculation of flexural strength

Factor	SS	df	Mq	F count	F table	SS'	P %
A	82,78	1	82,78	25,49	4,00398	79,53	0,18
B	60,82	1	60,82	18,72	4,00398	57,57	0,13
C	58,02	1	58,02	17,86	4,00398	54,77	0,12
D	58,11	1	58,11	17,89	4,00398	54,86	0,12
Error	191,65	59	3,25				
Total	451,38	63					

Table 6. The results of the ANOVA dry shrinkage calculation

Factor	SS	df	Mq	F count	F table	SS'	P %
A	21,390625	1	21,3906	31,2219	4,00398	20,7055	0,19606
B	9,765625	1	9,76563	14,254	4,00398	9,08051	0,08598
C	17,015625	1	17,0156	24,8361	4,00398	16,3305	0,15463
D	17,015625	1	17,0156	24,8361	4,00398	16,3305	0,15463
Error	40,421875	59	0,68512				
Total	105,60938	63					

IV.2.2. Calculation of the signal-to-noise ratio (SNR)

The results of the calculation of the signal-to-noise ratio for the flexural strength and dry shrinkage of ceramics can be seen in the following table.

Table 7. The results of the SNR calculation
for flexural strength

Trial	Column Number				SNR
	A	B	C	D	
1	1	1	1	1	44.50
2	1	1	2	2	43.86
3	1	2	1	2	44.70
4	1	2	2	1	44.58
5	2	1	1	1	44.69
6	2	1	2	2	45.31
7	2	2	1	2	44.72
8	2	2	2	1	44.96
Average					**44,67**

Table 8. The result of the SNR
dry shrinkage calculation

Trial No	Column Number				SNR
	A	B	C	D	
1	1	1	1	1	-14,64
2	1	1	2	2	-12,07
3	1	2	1	2	-15,28
4	1	2	2	1	-14,11
5	2	1	1	1	-13,57
6	2	1	2	2	-6,65
7	2	2	1	2	-12,01
8	2	2	2	1	-13,35
Average					**-12,71**

IV.2.3. Calculation of the effect of each factor

After all the effects of each factor are calculated, then the maximum difference is sought for each factor and the ranking of each factor is determined in order of the factors that have the greatest difference. The complete calculation results can be seen in Tables 9 and Tables 10.

Table 9. Effects of Each Flexural Strength Factor

	Control factor			
	A	B	C	D
Level 1	44,41	44,59	44,65	44,68
Level 2	44,92	44,74	44,68	44,65
Difference	0,51	0,15	0,03	0,03
Rank	**1**	**2**	**3**	**4**

Table 10. Effects of Each Dry Shrinkage Factor

	Control factor

	A	B	C	D
Level 1	-14,03	-11,73	-13,88	-13,92
Level 2	-11,39	-13,69	-11,55	-11,50
Difference	2,63	1,95	2,33	2,41
Rank	**1**	**4**	**3**	**2**

1) Calculation of Quality Loss, Quality Loss normalization, and Total Normalized Quality Loss (TNQL)

The next step is to calculate the quality loss, normalization of quality loss, and total normalization of quality loss.

2) Calculation of Multiple Response Signal to Noise ratio (MRSN)

The complete calculation results of the Multiple Response Signal to Noise ratio can be seen in Table 11.

Table 11. Calculation results of the Multi Response Signal to Noise Ratio

No	A	B	C	D	MRSN
1.	1	1	1	1	-1,03
2.	1	1	1	2	-1,94
3.	**1**	**1**	**2**	**1**	**-0,31**
4.	1	1	2	2	-1,66
5.	1	2	1	1	-1,56
6.	1	2	1	2	-0,92
7.	1	2	2	1	-1,33
8.	1	2	2	2	-2,24
9.	2	1	1	1	-1,66
10.	2	1	1	2	-2,62
11.	2	1	2	1	-1,07
12.	2	1	2	2	-3,57
13.	2	2	1	1	-2,16
14.	2	2	1	2	-2,30
15.	2	2	2	1	-1,83
16.	2	2	2	2	-2,99

3) Confirmation Experiment Results

Based on the data processing that has been carried out, the optimum factor level combination is Godean soil composition at level 1, Kasongan soil composition at level 1, sand composition at level 2, and combustion at level 1. With this combination, confirmation experiments are carried out for flexural strength and shrinkage. the dry ceramic body which results are shown in Table 12 and Table 13.

Table 12. The experimental results confirm flexural strength

	Noise Factor				Average	SNR
Confirmation	**1**	**2**	**1**	**2**		

experiment result	21,77	21,77	21,61	21,77	21,87	44,86
	23,05	21,61	21,77	21,61		

Table 13. Experimental results confirm dry shrinkage

	Noise Factor				Average	SNR
Confirmation	**1**	**2**	**1**	**2**		
experiment result	5	4	4	4	4,5	-13,12
	4	5	5	5		

4) *Confidence interval* for $\mu_{prediksi}$ dan $\mu_{konfirmasi}$

The 95% confidence interval for the prediction of process mean (F (0.05; 1; 29) = 4.18; MSe = 3.25) for the flexural strength response variable is

$$\hat{\mu}_{prediksi} - CI \le \mu \le \hat{\mu}_{prediksi} + CI$$

$$43{,}2 \le \mu \le 45{,}46$$

The confidence interval for predicting the process means in the confirmation experiment is the calculation of the SNR confidence interval (F (0.05; 1; 29) = 4.18; MSI = 3.25) for the flexural strength response variable is

$$\hat{\mu}_{konfirmasii} - CI \le \mu \le \hat{\mu}_{konfirmasii} + CI$$

$$43{,}14 \le \mu \le 46{,}58$$

The 95% confidence interval for the prediction of process mean (F (0.05; 1; 29) = 4.18; MSe = 3.25) for the dry loss response variable was

$$\hat{\mu}_{prediksi} - CI \le \mu \le \hat{\mu}_{prediksi} + CI$$

$$-13{,}57 \le \mu \le -12{,}53$$

The 95% confidence interval for the prediction of process mean (F (0.05; 1; 29) = 4.18; MSe = 3.25) for the dry loss response variable was

$$\hat{\mu}_{konfirmasii} - CI \le \mu \le \hat{\mu}_{konfirmasii} + CI$$

$$-13{,}91 \le \mu \le -12{,}33$$

IV.3. Results Analysis

IV.3.1.The effect of each factor's effect on each response

For the flexural strength response variable, the quality characteristics used are larger the better. Based on the calculation of the effect of each factor for the flexural strength response variable in Table 9, it is found that the optimal process parameter settings for making ceramics that produce the maximum flexural strength are A2 (3 parts Godean clay composition), B2 (3 parts Kasongan clay composition), C2 (3 parts composition). sand 1 part), D1 (burning using an open tub). For the dry shrinkage response variable, the quality characteristics used are smaller the better. Based on the calculation of the effect of each factor for the dry shrinkage response variable in Table 10, it is found that the optimal process parameter settings for making ceramics that produce minimal dry shrinkage are A2 (3 parts Godean clay composition), B1 (1 part Kasongan clay composition), C2 (composition 1 part sand), D2 (burning using a closed tub).

IV.3.2. Simultaneous determination of the optimal process parameters of the two response variables using MRSN

The manufacture of ceramics with maximum flexural strength and minimal dry shrinkage results in different optimal process parameter settings, so to determine the optimal process parameter settings for the two response variables simultaneously using MRSN. Based on calculations with the MRSN procedure, it can be seen that the optimal parameter setting is simultaneously found in the combination of factors and levels with the largest MRSN value so that the optimal process parameter setting for the flexural strength and dry shrinkage response of the ceramic body simultaneously is A1 (2 parts Godean soil composition), B1 (1 part kasongan soil composition), C2 (1 part sand composition), and D1 (burning using an open tub).

IV.3.3. Analyze the results of the confirmatory experiment

From the calculation of the confidence interval for the $\mu_{predict}$ and $\mu_{confirmation}$ of the response of flexural strength and dry shrinkage, it can be seen that both of them have a slice between the $\mu_{prediction}$ and the $\mu_{confirmation}$, which is between $43.2 \leq \mu \leq 45.46$ with $43.14 \leq \mu \leq 46.58$ and $-13.57 \leq \mu \leq -12.53$ with $-13.91 \leq \mu \leq -12.33$.

V. CONCLUSION AND FURTHER RESEARCH

Based on data processing and analysis of the results that have been done, conclusions and further research can be drawn:

a. The optimal process parameter setting that produces maximum ceramic flexural strength and minimal ceramic dry shrinkage simultaneously with the Taguchi multi-response method using MRSN in the manufacture of ceramics at the Kasongan Ceramics UKM center is 2 parts Godean soil composition, 1 part slack soil composition, 1 part sand composition, and burning using an open tub.
b. The calculation of the confidence interval for the µpredict and µconfirmation of the flexural strength and dry shrinkage response variables shows that both of them have a slice between the predicted and the µconfirmation. this can be applied to the industrial world en masse.
c. For further research, as a comparison to the parameter optimization results that have been obtained, it can be done to determine the optimal process parameters using the Taguchi multi-response method with methods other than MRSN.

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