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by Hernadewia Hernadewita

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Hernadewita [a], Rochmad, I. [b], Hendra [c], Hermiyetti [d], Yuliani, E.N.S.[e]

[a,b,e] Magister of Industrial Engineering, Mercu Buana University, Jl. Meruya Selatan, Jakarta, Indonesia
[c]Mechanical Engineering, University of Bengkulu, Jl. Kandang Limun, Bengkulu, Indonesia.
[d]Faculty of Economic Social Science, Bakrie University, Jl. HR Rasuna Said, Jakarta Selatan, Indonesia.

[a]hernadewita@mercubuana.ac.id , [a] imb_rochmad@yahoo.co.id

Abstract: Taguchi method is one of a design of experimental (DOE), by using statistical approach to optimize the process parameters and maintaining the minimum variability and also improve the quality of product. Based on data characterisation, Nominal is Best in Taguchi methods is suitable application in this study. Its describe the procedures and steps that occur in DOE to find an optimum quality parameter corresponding quality characterisation. Nominal is the best applied in milling process of pulp on the hydrapulper with pulp freeness 650 Canadian Standard Freeness (CSF). The result is shown by orthogonal array, Signal-to-Noise (S/N) Ratio and analysis of variances (ANOVA). Three factors cosidered in this study and namely the composition of pulp (waste paper), pulp consistency and milling time. The experiment will conducted after determination of each level and the appropriate orthogonal array was selected. After measuring of pulp freeness produced by the pulp milling on the hydrapulper, then Signal-to-Noise (S/N) Ratio is calculated. As the conclussion, the factors and levels of optimum freeness obtained, pulp composition in level 1 (100%), pulp consistency at level 2 (8%) and milling time factor in level 2 (45 minutes). The result of experimental verification was interpreted in the conclusion.
Keywords: Taguchi, DOE, pulp, hydrapulper, Nominal is the Best, ANOVA.

1 Introduction

In the globalization era, the competition among the business is very tight. One is shown by the development of materials input in industry. Its indicated by arising on launching the new products with variety of brands into the market, either national and international. In such situation, the main problem needs to be solve by businesses in order to survive is by giving focused on satisfaction to customers compared to the other factors.

There is no doubt that the main factor determining of customer satisfaction is the quality of product or services. Organizations or companies which meet quality requirement of products and services will be satisfying the customer needs. In fullfilness of customer satisfaction, as one of the fiber cement company in Indonesia, PT. BBI is committed to constantly improve their competitiveness and seize in a larger market, thus increasing in the quality of products and services as one of the determinants factor of customer satisfaction.

As one of the flagship products of PT. BBI is a corrugated fiber cement, which is produced in Sheet Machine, Line I to IV. Which is one of main content are milleing pulp in hydrapulper with specific freeness of 650 Canadian Standard

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Freeness (CSF). The freeness of the pulp mill on hydrapulper (Fatoki et al., 2015) currently very varietive, so that, it will have an impact to overall quality of fiber cement for corrugating roof. To improve the quality of the pulp production, so then, its conducted Taguchi experimental design approach with characterisation of quality by nominal is the best, in achieving the freeness of milled pulp of 650 CSF.

The objectives in this study was to determine the factors that influence the quality of the pulp slurry freeness and examine of each level of optimal factor for the improvement of the quality of the pulp milling on the hydrapulper.

2 Taguchi Method

This study is used an experimental design approach with the application of Taguchi method. Taguchi method is one of a new method in the field of engineering that objectives to improve the quality of products and processes and the mean time will costs and resources to a minimum (Taguchi, 1993; Kawamura, 2010; Athreya and Venkatesh, 2012; Bellavendram 1995; Dobrzański, 2007; Hassan et al., 2012; Kamarudin et al., 2004; Lajis et al., 2009; Roy, 2010; Verma et al., 2012; Yadav et al., 2012). The objective of Taguchi method is to meet the product robust against noise, as it is often referred as the Robust Design. Robust Design method, also called the Taguchi Method, pioneered by Dr. Genichi Taguchi, greatly improves engineering productivity. By consciously considering the noise factors (environmental variation during the product's usage, manufacturing variation, and component deterioration) and the cost of failure in the field the Robust Design method helps ensure customer satisfaction. Robust Design focuses on improving the fundamental function of the product or process, thus facilitating flexible designs and concurrent engineering. Indeed, it is the most powerful method available to reduce product cost, improve quality, and simultaneously reduce development interval. As the definition of quality according to Taguchi is loss received by the public since the product was shipped. Taguchi's philosophy of quality consists of four concepts (Taguchi, 1993), as:

1. Quality should be designed into the product and not just duing control by quality check.
2. The best quality is achieved by minimising the deviation from the target.
3. Products must be designed to be robust against environmental factors that could not be controlled.
4. The cost of quality should be measured in a function of a certain standard deviation, so that the loss should be measured in the whole system.

Taguchi method characterise as off-line quality control, which means as preventive quality control in product design or production process before arriving at the shop floor level. Off-line quality control is determined at the beginning of the life cycle of product improvement at the beginning of the product (to get right first time). Taguchi contribution to quality are:

1. Loss Function: Represents the loss produced by the people (producers and consumers) due to the quality produced. For producers with the cost of quality carried out by customers is their dissatisfaction or frustration of products purchased or used because of poor quality.
2. Orthogonal Array: Used to design an experiment that efisisen and used to analyze experimental data. Orthogonal array is used to determine the minimum number of experiments that can give as much information as possible all factors that influence the parameter. The most important part of the orthogonal array lies in the selection level combination of input variables for each experiment.
3. Robustness: Minimizing the sensitivity of the system to the sources of variation.

Table 2.1. Determination of Total Level and Level Value Factor.

Code	Control Factors	Unit	Level 1	Level 2	Level 3
A	Pulp composition (waste paper)	%	100	90	80
B	Pulp Consistency	%	4	8	12
C	Milling time	minute	30	45	60

Table 2.2. Results of experiments with orthogonal array $L_{27}(3_{13})$.

Experiment	Factors dan Interaction													Replication (CSF)			Total	Mean
	1	2	3	4	5	6	7	8	9	10	11	12	13	1	2	3		
	A	B	AxB(1)	AxB(2)	C	AxC(1)	AxC(2)	e	e	e	e	e	e					
1	1	1	1	1	1	1	1	e	e	e	e	e	e	640	630	640	1910	636.667
2	1	1	1	1	2	2	2	e	e	e	e	e	e	610	620	630	1860	620.000
3	1	1	1	1	3	3	3	e	e	e	e	e	e	620	610	620	1850	616.667
4	1	2	2	2	1	1	1	e	e	e	e	e	e	660	670	660	1990	663.333
5	1	2	2	2	2	2	2	e	e	e	e	e	e	660	650	650	1960	653.333
6	1	2	2	2	3	3	3	e	e	e	e	e	e	610	630	620	1860	620.000
7	1	3	3	3	1	1	1	e	e	e	e	e	e	690	680	690	2060	686.667
8	1	3	3	3	2	2	2	e	e	e	e	e	e	660	660	670	1990	663.333
9	1	3	3	3	3	3	3	e	e	e	e	e	e	630	650	640	1920	640.000
10	2	1	2	3	1	2	3	e	e	e	e	e	e	670	690	670	2030	676.667
11	2	1	2	3	2	3	1	e	e	e	e	e	e	650	650	670	1970	656.667
12	2	1	2	3	3	1	2	e	e	e	e	e	e	640	630	630	1900	633.333
13	2	2	3	1	1	2	3	e	e	e	e	e	e	680	670	670	2020	673.333
14	2	2	3	1	2	3	1	e	e	e	e	e	e	660	650	680	1990	663.333
15	2	2	3	1	3	1	2	e	e	e	e	e	e	640	620	630	1890	630.000
16	2	3	1	2	1	2	3	e	e	e	e	e	e	690	690	710	2090	696.667
17	2	3	1	2	2	3	1	e	e	e	e	e	e	680	670	660	2010	670.000
18	2	3	1	2	3	1	2	e	e	e	e	e	e	640	650	640	1930	643.333
19	3	1	3	2	1	3	2	e	e	e	e	e	e	680	670	680	2030	676.667
20	3	1	3	2	2	1	3	e	e	e	e	e	e	660	660	660	1980	660.000
21	3	1	3	2	3	2	1	e	e	e	e	e	e	640	630	630	1900	633.333
22	3	2	1	3	1	3	2	e	e	e	e	e	e	680	680	700	2060	686.667
23	3	2	1	3	2	1	3	e	e	e	e	e	e	660	660	670	1990	663.333
24	3	2	1	3	3	2	1	e	e	e	e	e	e	630	640	630	1900	633.333
25	3	3	2	1	1	3	2	e	e	e	e	e	e	710	700	690	2100	700.000
26	3	3	2	1	2	1	3	e	e	e	e	e	e	680	680	670	2030	676.667
27	3	3	2	1	3	2	1	e	e	e	e	e	e	650	670	670	1990	663.333
Average																		656.914

2.1 Taguchi Design of Experiments

Taguchi experimental design is an assessment simultaneously to two or more factors (parameters) affecting the ability of the average or the variability of the combined results of the features of the product or process (Taguchi, 1993). Some of the steps proposed by Taguchi to experiment systematically, namely:

a. Formulation of the problem

b. Experimental purposes

c. Determination of the dependent variable

d. Identify the factors (independent variables)

e. Separation of control factors and noise factors

f. Specifies the number of levels and the level of each factor

g. The calculation of degrees of freedom

h. Selection of an orthogonal matrix

i. Placement of the factors and the interaction space into an orthogonal array

j. Implementation of the experiment according to an orthogonal array

k. Analyzing the experimental data with ANOVA, calculate the optimal quality prediction.

l. The implementation of the verification experiment.

3 Result

Based on Taguchi experimental and the result to the orthogonal array, the data processed came out as follows Table 3.1 to 3.8.

Table 3.1. Factors Interaction Solutions A and B.

Interaction	B_1	B_2	B_3
A_1	624.444	645.556	663.333
A_2	655.556	655.556	670.000
A_3	656.667	661.111	680.000

To reach the intended target (nominal is the best), the determination of the optimal factor level is the result on the test that approach the pulp freeness on 650 CSF. So that, the optimal

Table 3.2. Response Pulp Freeness Average of Factors Effect.

	A	B	(AxB)1	(AxB)2	C	(AxC)1	(AxC)2
Level 1	644.444	645.556	651.852	653.333	677.407	654.815	656.296
Level 2	660.370	654.074	660.370	657.407	658.519	657.037	656.296
Level 3	665.926	671.111	658.519	660.000	634.815	658.889	659.259
Variance	21.481	25.556	8.519	6.667	42.593	4.074	2.963
Rank	3	2	4	5	1	6	7

Table 3.3. Analysis of Variance Combined Pulp Freeness Average.

Sources	v	SS	MS	F - Ratio	F- Table
A	2	2,237.860	1,118.930	21.839	3.007
B	2	3,047.737	1,523.868	29.743	3.007
AxB(1)	4	361.317	90.329	1.763	3.007
AxB(2)			Pooled (III)		
C	2	8,198.354	4,099.177	80.008	3.007
AxC(1)			Pooled (II)		
AxC(2)			Pooled (I)		
Error	16	819.753	51.235	-	-
Total	26	14,665.021	-	-	-

Table 3.4. Percentage Constribution.

Sources	v	SS	MS	SS'	ρ(%)
A	2	2,237.860	1,118.930	2135.391	14.561
B	2	3,047.737	1,523.868	2945.267	20.084
AxB(1)	4	361.317	90.329	156.379	1.066
C	2	8,198.354	4,099.177	8095.885	55.205
Error	16	819.753	51.235	-	-
Total	26	14,665.021	-	-	-

Table 3.5. Response S / N Ratio Pulp Freeness of Factors Effect.

	A	B	(AxB)1	(AxB)2	C	(AxC)1	(AxC)2
Level 1	25.986	26.238	27.232	28.289	29.343	24.717	25.741
Level 2	26.709	25.922	26.399	25.045	24.549	26.404	26.412
Level 3	26.971	27.506	26.033	26.332	25.774	28.544	27.728
Variance	0.985	1.584	1.199	3.244	4.794	3.827	1.987
Rank	7	5	6	3	1	2	4

Table 3.6. Factors Interaction Solutions.

Interaction	B_1	B_2	B_3	Interaction	C_1	C_2	C_3
A_1	28.079	23.686	26.191	A_1	26.121	23.686	28.150
A_2	26.013	27.287	26.826	A_2	30.303	25.877	23.947
A_3	24.621	26.791	29.499	A_3	31.604	24.084	25.224

Table 3.7. Analysis of Variance Combined S/N Ratio Pulp Freeness.

Sources	v	SS	MS	SS'	ρ(%)
B	2	12.649	6.325	-19.567	-4.217
AxB(2)	4	48.029	12.007	-16.405	-3.535
C	2	111.667	55.834	79.450	17.121

Table 3.8. Percent contribution of S/N Ratio Pulp Freeness.

Sources	v	SS	MS	F-Ratio	F-Table
A		Pooled I			
B	2	12.649	6.325	0.393	3.112
AxB(1)		Pooled II			
AxB(2)	4	48.029	12.007	0.745	3.112
C	2	111.667	55.834	3.466	3.112

Table 4.1. Interpretation of Measurement Results of Pulp Freeness Average.

Pulp freeness Average		Prediction	Optimize
Taguchi Experimental	Average (m)	643.210	643.210±4.380
	S/N Variability	22.589	22.589±3.524
Verification Experimental	Average (m)	646.210	646.210±6.829
	S/N Variability	15.589	15.589±7.860

combination of factors level are:
A1 = Waste paper 100%.
B2 = Pulp Consistency 8%.
C2 = Milling time for 45 minutes.
The percentage contribution from the Table 3.4 shows that the factor C (milling time) was contributed to the most of average freeness of the pulp, which 55.205% followed by factor B (consistency) 20.084% and factor A (waste paper) 14.561%.

To obtain the target of nominal is the best, combination of optimal factor level achieved in the average value of S/N ratio is the lowest level of each factor, indicating the smaller of the value closer to the target. The optimum level factors are:
A1 = Waste paper 100%.
B2 = Pulp Consistency 8%.
C2 = Milling time for 45 minutes.

3.1 Analysis of Varians (ANOVA) S/N Ratio Pulp Freeness Average

The ANOVA for S/N Ratio Pulp Freeness Average is shown of Table 3.7 and Table 3.8. The percentage contribution from the Table 3.7 and 3.8, shows that the factor C (milling time) contributed to the most of average freeness of the pulp, which is 17.121% followed by interaction of factors AXC (1) 0.381% and an average interaction AXB (2) -3.535%.

4 Conclusions and Discussion

As the definition of pulp freeness on milling process is spread/decomposition of pulp fibers after the milling process, the measuring standard of freeness on industry are generalise in three types, such as; Canadian Standard freeness (CSF), Schopper Riegler (oSR) and Williams Slowness (s).

As the result from Taguchi experimental, it shown that the freeness of pulp produced from hydrapulper milling prediction increasing the quality (see Fig. 4.1). Also, as the experimental verification data showed an increasing in the quality of milling process significantly and the freeness of the pulp milled on hydrapulper more stable (see Fig. 4.2).

4.1 Research limitations

The accuracy of the results was strongly influenced by the choosen of the instruments. The

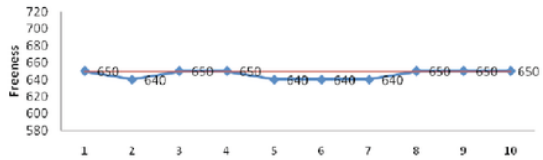

Figure 4.1. The Current Pulp Freeness Produced from Hydrapulper Milling.

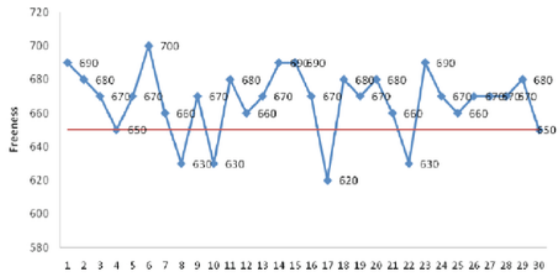

Figure 4.2. The Pulp Freeness Produced from Hydrapulper Milling On Experimental Verification.

suitable measuring instruments will be determining the accuracy on the result of study. Furthermore, reference to relevant support, with the access to reference study related will facilitate the next coming research in the same field and differences method and instruments. Number of limitations in the this study, are:

1. The measurement scale on range was used a multiply of 10. So that, the measuring results are less accuracy on readings than compared to the results of calculations verification on Taguchi experimental.
2. The lack of references on this study. In this study there was little impediment as a comparison. Furthermore, the comparison was used cross references study in the sense of the pulp.

The Taguchi design experimental is considered into the factors that influence the quality characteristization, without considering to the interference factors as also found in Selvaraj & Chandramohan (2010). Thus, the experiment was focused on the implementation of complexity and significant costs. As the engine noise is not included in this study, the effect of engine noise also can affect the accuracy and quality of experimental results.

5 Conclusion and Discussion

5.1 Conclusion

1. The quality improvement of the pulp freeness produced from hydrapulper milling was shown by Taguchi experimental design implementation with the character of nominal is the best (650 CSF). The obtained factors and the level of each factors that influence the pulp freeness produced from hydrapulper milling processing, as follows:
   a. The composition of recycled paper (waste paper) at the level 1 (100%).
   b. Pulp consistency at level 2 (8%).
   c. Milling time at level 2 (45 minutes).
2. The use of recycled paper of cement bags (waste paper) is decreased the production cost of the fiber cement roofing. As the price of recycled paper of cement bags are generally cheaper than new paper that used as an imported, and at the same time maintaining appropriate quality standards.

5.2 Discussion

In addition to the conclusions, the recommendation on more accurate and detail of experimental results to quality improvement are as follows:

1. Carefully use a measuring tube with a scale size and clearly, will avoid errors in reading, so it will produce accurate information or data that used as the experimental results.
2. The use of Taguchi experimental design can be developed, such as in engineering tests to find the best product quality in manufacturing line. And also improved the quality of product for fiber cement roofing and other products are affected by several factors and levels.

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