An Analysis of Implementation of Taguchi Method to Improve Production of Pulp on Hydrapulper Milling.

Dipabrata Banerjee[1*], Ajay Kumar Sahoo[2]
[1*]Assistant Professor, Department of Mechanical Engineering, Nalanda Institute of Technology, Bhubaneswar, Odisha, India
[2]Assistant Professor, Department of Mechanical Engineering, Nalanda Institute of Technology, Bhubaneswar, Odisha, India

*Corresponding author e-mail: dipabratabanerjee@thenalanda.com

.

Abstract: The Taguchi technique is a type of design of experiment (DOE), which uses statistical methods to optimise process parameters while preserving the least amount of variability and enhancing product quality. Nominal is Best in Taguchi techniques is an appropriate application in this study based on data characterisation. It outlines the stages and processes used in DOE to identify the best quality parameter for a given quality characterization. When milling pulp using a hydrapulper, nominal works best when the pulp freeness is 650 Canadian Standard Freeness (CSF). Signal-to-Noise (S/N) Ratio, orthogonal array, and analysis of variances are used to display the outcome (ANOVA). This study took into account three variables: pulp composition (waste paper), pulp consistency, and milling time. After each level has been determined and the suitable orthogonal array has been chosen, the experiment will be carried out. Signal-to-Noise (S/N) Ratio is computed after monitoring the pulp freeness created by the pulp milling on the hydrapulper. Conclusion: The pulp composition at level 1 (100%), the pulp consistency at level 2, and the milling time factor at level 2 all contributed to the optimum freeness obtained (45 minutes). At the conclusion, the experimental verification result was interpreted.

Keywords: Taguchi, DOE, pulp, hydrapulper, Nominal is the Best, ANOVA.

1 Introduction

The corporate world is currently experiencing intense competition. The evolution of industrial input materials demonstrates one. It may be seen when new products with various brands, both domestically and internationally, are introduced to the market. Businesses in this situation need to focus more on providing customer satisfaction to clients than on other things in order to thrive.

There is no question that the quality of the goods or services is the primary determinant of customer happiness. Companies or organisations which serve the needs of the consumer and meet the standards of quality for goods and services. Being one of Indonesia's leading fibre cement companies, PT. BBI is dedicated to continuously enhancing their competitiveness and capturing a bigger market, increasing the quality of their goods and services as one of the key factors of customer satisfaction.

Corrugated fibre cement, one of PT. BBI's signature products, is created in Sheet Machine, Lines I to IV. One of the key contents is milling pulp in a hydrapulper with 650 Canadian Standardr satisfaction for specific freeness.

Freeness (CSF) (CSF). The existing level of variability in the pulp mill's freedom on the hydrapulper (Fatoki et al., 2015) will affect the overall quality of the fibre cement used to make corrugated roofs. Thus, the Taguchi experimental design strategy used to characterise quality by nominal is the best in reaching the freeness of milled pulp of 650 CSF in order to increase the quality of pulp manufacturing.

The goals of this study were to identify the variables that affect the degree of pulp slurry freeness and to analyse each level of the best variable for enhancing the quality of pulp milling on the hydrapulper.

2 Taguchi Method

This study is used an experimenal 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; Dobrzañski, 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, since the goods was supplied, the public has suffered a loss. The four pillars of Taguchi's quality philosophy are as follows: (Taguchi, 1993) ,as:

1. Rather than relying just on quality control through inspection, quality should be built into the product.
2. Reducing the variance from the aim yields the best quality.
3. Goods need to be made to withstand environmental variables that are uncontrollable.
4. The cost of quality should be calculated as a function of a specific standard deviation, allowing for the measurement of loss across the entire 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 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 souces 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. 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'	p(%)
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.

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).

Research limitations

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

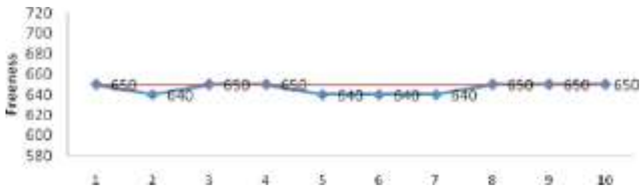

Figure 4.1. The Current Pulp Freeness Produced from Hydrapulper Milling.

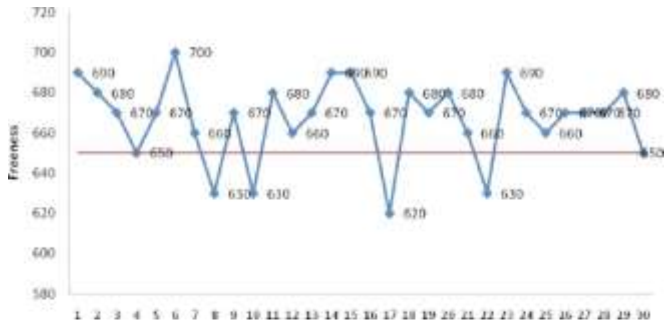

Figure 4.2. The Pulp Freeness Produced from Hydrapulper Milling On Experimental Verification.

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. 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

Conclusion

a. Taguchi experimental design implementation with the character of nominal is the best demonstrated the improvement in pulp freeness produced by hydrapulper milling (650 CSF). The following are the determined factors and their relative weights as they relate to the pulp freeness that results from the hydrapulper milling processing:
b. b. The level 1 (100%) recycled paper (waste paper) composition.
c. Pulp consistency at level 2 (8%).
d. Milling time at level 2 (45 minutes).
e.

The cost of manufacturing fibre cement roofing is reduced by using recycled paper for cement bags (waste paper). As recycled paper for cement bags is typically less expensive than new paper that is imported, acceptable quality standards are nevertheless being upheld.

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.

References

Athreya, S., Venkatesh, Y.D. (2012). Application Of Taguchi Method For Optimization Of Process Parameters In Improving The Surface Roughness Of Lathe Facing Operation. International Refereed Journal of Engineering and Science (IRJES). 1(3), 13-19.

Bellavendram, N. (1995). Quality by Design: Taguchi Techniques for Industrial Experimentation. Prentice Hall, London.

Dobrzañski, L.A. (2007). Application of Taguchi Method in The Optimisation of Filament Winding of Thermoplastic Composites. International Scientific Journal, 28(3). Published monthly as the organ of the Committee of Materials Science of the Polish Academy of Sciences.

Fatoki, J.G., Omoniyi, T.E., Onilude, M.A. (2015). Design and Fabrication of a Hydrapulper for Disintegrating Disused Tetra Pack® Beverage Cartons. European International Journal of Science and Technolog,4(6), 113-123.

Hassan, K., Kumar, A., Garg, M.P. (2012). Experimental Investigation of Material Removal Rate in CNC Turning Using Taguchi Method. International Journal of Engineering Research and Applications, 2(2), 1581-1590.

Kamarudin, S., Zahid, A., Wan, K.S. (2004). The Use of taguchi Method In Determining The Optimum Plastic Injection Moulding Parameters For The Production of A Consumer Product. Jurnal Mekanikal. Disember 2004, Bil.18, 98-110.

Kawamura, T. (2010). Performance Measures for Robust Design and Its Applications. 4th International Workshop on Reliable Engineering Computing (REC 2010). ISBN: 978-981-08-5118-7. Published by Research Publishing Services.

Lajis, M.A., Radzi, H.C.D., Amin, A.K.M.N. (2009). The Implementation of Taguchi Method on EDM Process of Tungsten Carbide. European Journal of Scientific Research, 26(4), 609-617.

Roy, R.K. (2010). A Primer on the Taguchi Method. 2nd Edition. Society of Manufacturing Engineers. Dearborn: Michigan. USA.

Selvaraj, D.P., Chandramohan, P. (2010). Optimization of Surface Roughness of AISI 304 Austenitic Stainless Steel in Dry Turning Operation Using Taguchi Design Method. Journal of Engineering Science and Technology, 5(3), 293-301.

Taguchi, G. (1993). Taguchi on Robust Technology Development: Bringing Quality Engineering Upstream. Okhen Associates. Tokyo. Japan. ASME Press New York. https://doi.org/10.1115/1.2905506

Verma, J., Agrawal, P., Bajpai, L. (2012). Turning Parameter Optimization for Surface Roughness of ASTM A242 Type-1 Alloys Steel by Taguchi Method. International Journal of Advances in Engineering & Technology, 3(1), 255-261.

Yadav, U.K., Narang, D., Attri, P.S. (2012). Experimental Investigation and Optimization of Machining Parameters for Surface Roughness in CNC Turning by Taguchi Method. International Journal of Engineering Research and Applications, 2(4), 2060-2065.