Determining a combination of factors on rubber end manufacturing using taguchi method at PT. Agronesia Bandung

by Wahyukaton -

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Sustainable development in industry and management

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PREFACE

This issue is published in line with the Tenth International Seminar on Industrial Engineering and Management (10th ISIEM). The articles cover a broad spectrum of topics including Quality Engineering Management, Decision Support System and Artificial Intelligent, Ergonomics, Supply Chain Management, Production System, Operation Research, and Industrial Management. The 87 articles provide an overview of critical research issues reflecting on past achievements and future challenges. Those papers were selected from 77 out of 87 abstracts. This statistics shows the high competition to get published on this proceeding.

This issue and the seminar become special as more delegates come and join us from various countries as well as universities compared to previous years. We host 82 delegates both from abroad and local. The 10th ISIEM is hosted by seven universities, i.e. Esa Unggul University, Trisakti University, Tarumanagara University, Al Azhar Indonesia University, Atma Jaya Catholic University of Indonesia, Pasundan University and Pancasila University.

Special thanks go to Prof. Matteo Mario Savino from University of Sannio, Italy; Dr. Nutthapol Asadathorn, Executive Director of TRR Sugar Refinery Group, Thailand; and Dr. Syuhaida Ismail from University of Technology Malaysia, for their contribution as keynote speakers. We are also grateful to all reviewers, for their commitment, effort and dedication in undertaking the task of reviewing all of the abstracts and full papers. Reviewing a large number of submissions in a relatively short time frame is always challenging. Without their help and dedication, it would not be possible to produce this proceeding on time. I highly appreciate all members of ISIEM committees (advisory, steering, and organizing committees) for their mutual efforts and invaluable contribution for the success of the seminar.

Have a pleasant seminar

Dr. Iphov Kumala Sriwana
Chair

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Quality Engineering & Management (QM)

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Abstract. Rubber end is one of products that manufactured by PT. Agronesia Bandung. These products experienced defect and unconformity to the standard which is bubble trapped in rubber end products. This defect can be found from 3 factors – control factor, which are material thickness, temperature, and shift. Material thickness has 3 levels, which are 3 mm, 5.5 mm, and 7 mm; temperature has 3 levels, which are, 35^0 C - 40^0 C, 40^0 C - 45^0 C, and 45^0 C - 55^0 C; while shift has 3 levels, which are shift 1, shift 2, and shift 3. To solve the problem, Taguchi method is used to have the right combination of those 3 factors to produce rubber end. First step is selecting factors and determining level that will be a base for selecting orthogonal matrix, and then determining S/N ratio and analysis of variance. The result is factors combinations are material thickness at level 2 of 5.5 mm, temperature at level 3 of 45^0 C - 55^0 C, and shift at level 1 of shift I.
Keywords: taguchi method, analysis of variance, signal to ratio, defects

1. Introduction

PT. Agronesia is a rubber manufacture, and one of their product is rubber end. The company experience the problems on this rubber end that are defects on the products. These defects are bubble trapped, bare, raw, exceed dimension, and thickness, and these defects causing the products will be reworked or even rejected. Figure 1 shows that the most occurred defect is bubble which is 8 occurrences from 16 or 50%, so that this defect needs a special attention to reduce defects ratio and to improve the product quality.

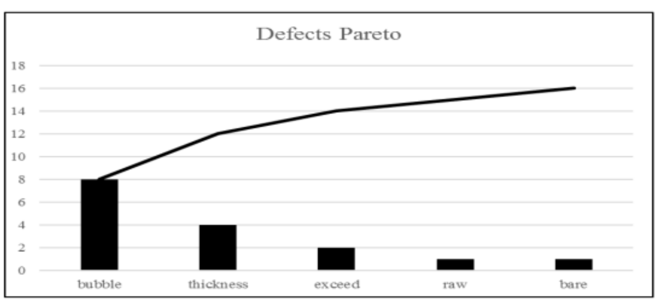

Figure 1. Defects Pareto

2. Method

In business, engineering and manufacturing, quality has a pragmatic interpretation as the *non-inferiority* or *superiority* of something; it's also defined as *fitness for purpose*. Quality is a perceptual, conditional, and somewhat subjective attribute and may be understood differently by different people. Consumers may focus on the specification quality of a product/service, or how it compares to competitors in the marketplace. Producers might measure the conformance quality, or degree to which the product/service was produced correctly [2].

2.1 Experimental design

Experimental design is the design of any task that aims to describe or explain the variation of information under conditions that are hypothesized to reflect the variation. The term is generally associated with true experiments in which the design introduces conditions that directly affect the variation, but may also refer to the design of quasi-experiments, in which natural conditions that influence the variation are selected for observation [4].

In its simplest form, an experiment aims at predicting the outcome by introducing a change of the preconditions, which is reflected in a variable called the predictor (independent). The change in the predictor is generally hypothesized to result in a change in the second variable, hence called the outcome (dependent) variable. Experimental design involves not only the selection of suitable predictors and outcomes, but planning the delivery of the experiment under statistically optimal conditions given the constraints of available resources.

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The Taguchi method of quality control is an approach to engineering that emphasizes the roles of research and development, product design and product development in reducing the occurrence of defects and failures in products. The Taguchi method considers design to be more important than the manufacturing process in quality control and tries to eliminate variances in production before they can occur [8].

Taguchi refers to experimental design as "off-line quality control" because it is a method of ensuring good performance in the design stage of products or processes. Some experimental designs, however, such as when used in evolutionary operation, can be used on-line while the process is running [7].

2.3 Factors, factors level

1. Factors

Based on defects pareto, it can be determined that the independent variable is bubble trapped due to the most occurrence defect.

For dependent variable (factors) can be determined from the early researches will be material thickness, temperature, and shift.

Table 1. Variables, Factors

Variables	Factors	Classification
A	Material thickness	Factor Control
B	Temperature	Factor Control
C	Shift	Factor Control

Uncontrollable factors (noises) in this research are humidity, workers performance is excluded in the matrix, so that the experiment only applied to controllable factors by doing replication on each experiment.

2. Factors level

Material thickness

The material thickness is significantly influence for bubble trapped in rubber end. The product thickness is 20 – 21 mm, so that material thickness will be set in 3 levels as follows,

- Level 1 = 3 mm
- Level 2 = 5.5 mm
- Level 3 = 7 mm

Temperature

There are 3 levels for this factor, as follows

- Level 1 = 35 - 40 mm
- Level 2 = 40 - 45 mm
- Level 3 = 45 - 55 mm

Shift

Shift is the interval work to produce rubber end.
There are 3 levels for this factor, as follows

- Level 1 = shift 1
- Level 2 = shift 2
- Level 3 = shift 3

By applying Taguchi method, the quality of manufactured goods, and engineering designs are developed by studying variations. The Composite Principle Component has been optimized by using Taguchi method. Analysis of variance (ANOVA) has been conducted for Composite Principle Component to find the optimal process parameters. Signal to Noise (S/N) Ratio has been found for PCA to find the optimal levels of the process parameters. Finally, a conformation test has been made for three different materials and the results have been plotted. [3]

The Taguchi method was used to determine optimum conditions for tire rubber in asphalt concrete with Marshall Test. The tire rubber in asphalt concrete was explored under different experimental parameters including tire rubber gradation (sieve #10–40), mixing temperature (155–175 1C), aggregate gradation (grad. 1–3), tire rubber ratio (0–10% by weight of asphalt), binder ratio (4–7% by weight of asphalt), compaction temperature (110–135 1C), and mixing time (5–30 min). The optimum conditions were obtained for tire rubber gradation (sieve #40), mixing temperature (155 1C), aggregate gradation (grad. 1), tire rubber ratio (10%), binder ratio (5.5%), compaction temperature (135 1C), mixing time (15 min). [5]

3. Result and Discussion

Before orthogonal matrix is constructed, first the degree of freedom (DoE) has to be determined. DoE is meant to calculate the number of minimum experiments to inquire the observed factors.

Table 2. Degree of Freedom

Factor	Degree of Freedom	Total
A	3 – 1	2
B	3 – 1	2
C	3 – 1	2
	Total DoF	6

After the experiments were conducted, the orthogonal matrix L_9 (3^4) for bubble trapped as follows,

Table 3. Orthogonal Matrix L_9 (3^4)

Experiments	A	B	C	Error	Result			Sum	Mean
1	1	1	1	1	3	4	0	7	2.33
2	1	2	2	2	2	2	3	7	2.33
3	1	3	3	3	3	3	0	6	2.00
4	2	1	2	3	3	2	2	7	2.33
5	2	2	3	1	0	3	3	6	2.00
6	2	3	1	2	1	3	1	5	1.67
7	3	1	3	2	0	3	2	5	1.67
8	3	2	1	3	4	0	3	7	2.33
9	3	3	2	1	2	0	3	5	1.67
							Total	55	18.33
							Mean	6.11	2.04

In this experiment, orthogonal matrix L_9 (3^4) is chosen, so that a linear graphic standard which is necessary to the experiments as follows,

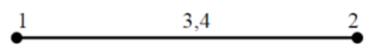

Figure 2. Linear Graphic of L_9 (3^4)

From the linear graphic in figure 2., it can be seen that factor A will be placed in column 1, factor B will be placed in column 2, factor C will be placed in column 3, and Error will be placed in column 4. The number of 1, 2, 3 are randomize process. Level on the orthogonal matrix column was made in number 1, 2, 3, etc. Or it can be done by using own method to describe the level, for example 0 and X, (+) and (–), L and H, to replace the number of 1, 2, 3 [6].

To find the factors that influence to bubble trapped, it needs to analyze by signal to noise (S/N) ratio in the analysis of variance. When the mean of responds was found, then the next step is to determine a robust design which is a design that will not affected by noise factor. The S/N which is been used is a quality characteristic, the smaller the better [6]. The quality of bubble trapped is good when the smallest bubble trapped is the better.

Table 4. Signal to Ratio (S/N)

Experiments	A	B	C	Error	Result			S/N
1	1	1	1	1	3	4	0	-9.21
2	1	2	2	2	2	2	3	-7.53
3	1	3	3	3	3	3	0	-7.78
4	2	1	2	3	3	2	2	-7.53
5	2	2	3	1	0	3	3	-7.78
6	2	3	1	2	1	3	1	-5.64
7	3	1	3	2	0	3	2	-6.37
8	3	2	1	3	4	0	3	-9.21
9	3	3	2	1	2	0	3	-6.37
							Total	-67.43
							Mean	-7.49

The mean of factor effect based on S/N ratio is an average of S/N respond from each particular levels and factors, the calculation was done based on the respond of experiments.

Table 5. Mean of S/N Ratio for Effect Factors

	A	B	C
Level 1	-8.17	-7.70	-7.07
Level 2	-6.99	-8.17	-8.09
Level 3	-7.31	-6.60	-7.31
Difference	1.19	1.11	1.02
Ranking	1	2	3
	A1	B3	C1

Table 5 shows that the setting of effected factors is factor C level 1, factor B level 3, and factor A level 2.

As the influence factors to the mean of bubble trapped were found, then to find a significant influence factors to S/N ratio can be done by construct a two-way analysis of variance model.

Table 6. Analysis of Variance for Bubble Trapped

Source	DoE	SS	MS	f
A	2	2.26	1.13	5.38
B	2	3.93	1.97	9.38
C	2	1.70	0.85	4.05
Error	20	4.11	0.21	
Total	26	12.01		

Test of hypothesis was done for all factors for 90% confidence level with $DoE_1 = 2$ and $DoE_2 = 20$, so that the $f_{(0.1;2,20)} = 2.59$.

1. Factor A
H_0: there is no effect of factor A to bubble trapped
H_1: there is an effect of factor A to bubble trapped
$f = 5.38 > f_{(0.1;2,20)} = 2.59$, reject H_0, there is an effect of factor A to bubble trapped
2. Factor B
H_0: there is no effect of factor A to bubble trapped
H_1: there is an effect of factor A to bubble trapped
$f = 9.38 > f_{(0.1;2,20)} = 2.59$, reject H_0, there is an effect of factor A to bubble trapped
3. Factor C
H_0: there is no effect of factor A to bubble trapped
H_1: there is an effect of factor A to bubble trapped
$f = 4.05 > f_{(0.1;2,20)} = 2.59$, reject H_0, there is an effect of factor A to bubble trapped

Table 7. Value and Percentage of Contribution for Each Factor

Factors	Value for Contribution (SS')	Contribution Percentage (ρ)
A	1.54	15.32
B	3.51	29.23
C	1.28	10.66

Based on the all calculations, a setting level design to reduce bubble trapped on rubber end product was found as follows,

Table 8. Setting Level Design

Factor	Level Chosen	Specification
Material Thickness	2	5.5 mm
Temperature	3	45^{O} C – 55^{O} C
Shift	1	I

4. Conclusion

1. The factors that causing bubble trapped defect on rubber end are,
    - Material thickness
    - Temperature
    - Shift
2. The setting level design to reduce defects are,
    - Factor A, material thickness is set to level 2 (5.5 mm.)
    - Factor B, temperature is set to level 3 (45^{O} C – 55^{O} C)
    - Factor C, shift is set to level 1 (shift I)

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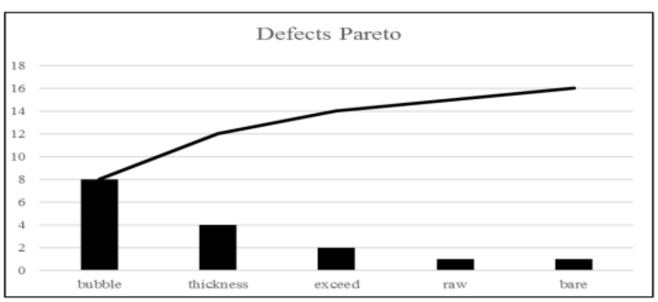

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1	1	1	1	1	3	4	0	7	2.33
2	1	2	2	2	2	2	3	7	2.33
3	1	3	3	3	3	3	0	6	2.00
4	2	1	2	3	3	2	2	7	2.33
5	2	2	3	1	0	3	3	6	2.00
6	2	3	1	2	1	3	1	5	1.67
7	3	1	3	2	0	3	2	5	1.67
8	3	2	1	3	4	0	3	7	2.33
9	3	3	2	1	2	0	3	5	1.67
							Total	55	18.33
							Mean	6.11	2.04

In this experiment, orthogonal matrix L_9 (3^4) is chosen, so that a linear graphic standard which is necessary to the experiments as follows,

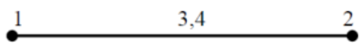

Figure 2. Linear Graphic of L_9 (3^4)

From the linear graphic in figure 2., it can be seen that factor A will be placed in column 1, factor B will be placed in column 2, factor C will be placed in column 3, and Error will be placed in column 4. The number of 1, 2, 3 are randomize process. Level on the orthogonal matrix column was made in number 1, 2, 3, etc. Or it can be done by using own method to describe the level, for example 0 and X, (+) and (−), L and H, to replace the number of 1, 2, 3 [6].

To find the factors that influence to bubble trapped, it needs to analyze by signal to noise (S/N) ratio in the analysis of variance. When the mean of responds was found, then the next step is to determine a robust design which is a design that will not affected by noise factor. The S/N which is been used is a quality characteristic, the smaller the better [6]. The quality of bubble trapped is good when the smallest bubble trapped is the better.

Table 4. Signal to Ratio (S/N)

Experiments	A	B	C	Error	Result			S/N
1	1	1	1	1	3	4	0	-9.21
2	1	2	2	2	2	2	3	-7.53
3	1	3	3	3	3	3	0	-7.78
4	2	1	2	3	3	2	2	-7.53
5	2	2	3	1	0	3	3	-7.78
6	2	3	1	2	1	3	1	-5.64
7	3	1	3	2	0	3	2	-6.37
8	3	2	1	3	4	0	3	-9.21
9	3	3	2	1	2	0	3	-6.37
							Total	-67.43
							Mean	-7.49

The mean of factor effect based on S/N ratio is an average of S/N respond from each particular levels and factors, the calculation was done based on the respond of experiments.

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Table 5. Mean of S/N Ratio for Effect Factors

	A	B	C
Level 1	-8.17	-7.70	-7.07
Level 2	-6.99	-8.17	-8.09
Level 3	-7.31	-6.60	-7.31
Difference	1.19	1.11	1.02
Ranking	1	2	3
	A1	B3	C1

Table 5 shows that the setting of effected factors is factor C level 1, factor B level 3, and factor A level 2.

As the influence factors to the mean of bubble trapped were found, then to find a significant influence factors to S/N ratio can be done by construct a two-way analysis of variance model.

Table 6. Analysis of Variance for Bubble Trapped

Source	DoE	SS	MS	*f*
A	2	2.26	1.13	5.38
B	2	3.93	1.97	9.38
C	2	1.70	0.85	4.05
Error	20	4.11	0.21	
Total	26	12.01		

Test of hypothesis was done for all factors for 90% confidence level with $DoE_1 = 2$ and $DoE_2 = 20$, so that the $f_{(0.1;2,20)} = 2.59$.

1. Factor A
H_0: there is no effect of factor A to bubble trapped
H_1: there is an effect of factor A to bubble trapped
$f = 5.38 > f_{(0.1;2,20)} = 2.59$, reject H_0, there is an effect of factor A to bubble trapped
2. Factor B
H_0: there is no effect of factor A to bubble trapped
H_1: there is an effect of factor A to bubble trapped
$f = 9.38 > f_{(0.1;2,20)} = 2.59$, reject H_0, there is an effect of factor A to bubble trapped
3. Factor C
H_0: there is no effect of factor A to bubble trapped
H_1: there is an effect of factor A to bubble trapped
$f = 4.05 > f_{(0.1;2,20)} = 2.59$, reject H_0, there is an effect of factor A to bubble trapped

Table 7. Value and Percentage of Contribution for Each Factor

Factors	Value for Contribution (SS')	Contribution Percentage (ρ)
A	1.54	15.32
B	3.51	29.23
C	1.28	10.66

Based on the all calculations, a setting level design to reduce bubble trapped on rubber end product was found as follows,

Table 8. Setting Level Design

Factor	Level Chosen	Specification
Material Thickness	2	5.5 mm
Temperature	3	45^{O} C – 55^{O} C
Shift	1	I

4. Conclusion

1. The factors that causing bubble trapped defect on rubber end are,
   - Material thickness
   - Temperature
   - Shift
2. The setting level design to reduce defects are,
   - Factor A, material thickness is set to level 2 (5.5 mm.)
   - Factor B, temperature is set to level 3 (45^{O} C – 55^{O} C)
   - Factor C, shift is set to level 1 (shift I)

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