Vol. 5, No. 9, September 2024
E-ISSN:2723 – 6692
P-ISSN:2723– 6595
http://jiss.publikasiindonesia.id/

Taguchi Approach to Defect Analysis on Electric Motor Conversion at PT. Electric Vehicle Trimotorindo

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KEYWORDS
Production Process; Taguchi; QC

ABSTRACT
Maintaining product quality can reduce the risk of defective products. The survival of a company is heavily reliant on product quality. In order to improve performance and reduce defects in the product process, PT. Electric Vehicle Trimotorindo employs the Taguchi approach in conjunction with the QC system. The goal of this research is to determine the product process of PT. Trimotorindo Electric Vehicle, identify the highest rejection rate, evaluate process capability, and propose improvements using the Kaizen system. This study uses the Taguchi system to optimize the product process of PT. Trimotorindo Electric Vehicles. After collecting data from the taguchi system, it can be concluded that the highest position of blights in a conversion process is in the electric current string.

Introduction

Indonesia is one of the most populous countries in Asia, and it has the opportunity to create more jobs and support economic development. Electric motors are essential components in a variety of industrial, vehicle, and household appliance applications. Quality control involves identifying defects or non-conformities in the production process and implementing corrective actions to minimize or eliminate those defects (Aldi & Rahmatullah, 2023; Tirtayasa et al., 2021).

The implementation of Industry 4.0 has enabled a flexible manufacturing system capable of producing different types of products at a lower cost (Durakovic & Halilovic, 2023; Guo et al., 2021; Javaid et al., 2022; Teja et al., 2022). The objectives of this study include analyzing defects using the Taguchi method that affect the production process in the conversion of electric motors and looking for factors that cause defects in electric motor components.

The high-efficiency motor design reduces friction and heat generation during operation. The materials used also affect the performance of the engine. For example, using magnetic materials with high magnetic permeability can improve motor performance. Operating conditions, such as machines operating at heavy loads or high temperatures, can also affect the machine's efficiency (Germann et al., 2021; Hasan et al., 2022; Quan et al., 2021).

Materials and Methods

The Taguchi method is a new methodology in the field of engineering that aims to improve the quality of products and processes and to reduce costs and resources to a minimum. This method is very effective for quality improvement and cost reduction, improvement in product manufacturing and reduction of product development costs (Setyo Pradana and Sulistiyowati 2022).

Taguchi's definition of quality is the loss received by the public since the product was shipped. The Taguchi concept is to improve the quality of manufactured goods by designing products or processes before they reach the production stage (Pramudita et al., 2022; Saleem et al., 2022; Sanjeevannavar et al., 2022).

Results and Discussions

From the results of observations and interviews with related parties at PT. Electric Vehicle Trimotorindo finally obtained information about the process of corruption of electric motorcycles, from the results of interviews and direct observations in the field, in the end it resulted in an electric motorcycle data and not too many people have explored the process of corruption from gasoline or conventional motorcycles to electric engines, therefore the author explores about electric motorcycles in the field of corruption.

Fishbone identification

This identification took from literature reviews and interviews with stakeholders, particularly in the Quality Control (QC) department and the electric motor conversion section, resulting in the identification of factors that affect quality characteristics. From the results of the observation of the data on the number of defects obtained in the 5-day observation time of the electric motor conversion process, it can be seen in the table below:

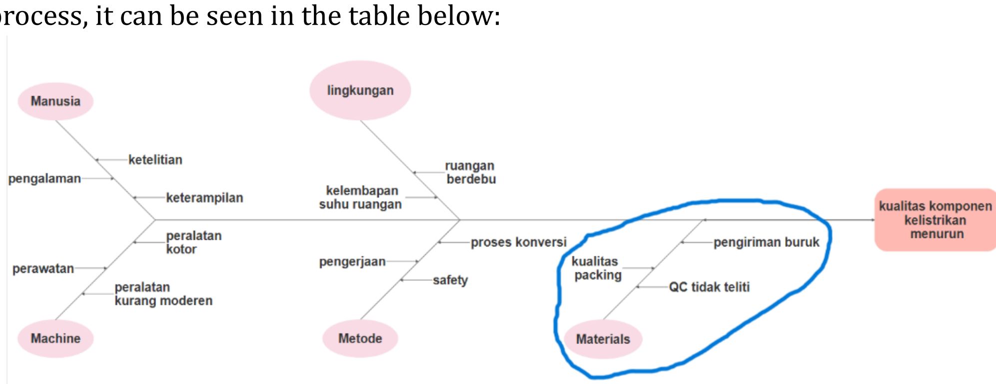

Figure 1 Fishbone diagram

The results of the observation of the data on the number of defects obtained in the 5-day observation time of the electric motor conversion process it can be seen in the table

Table 1 Total of damages per day

No	Day	Total of Damage	
1	Monday	8	2
2	Tuesday	7	2

3	Wednesday	9	3
4	Thursday	6	5
5	Friday	5	10

From this data, it can be concluded that the most damage is on Wednesday can be seen in the diagram below:

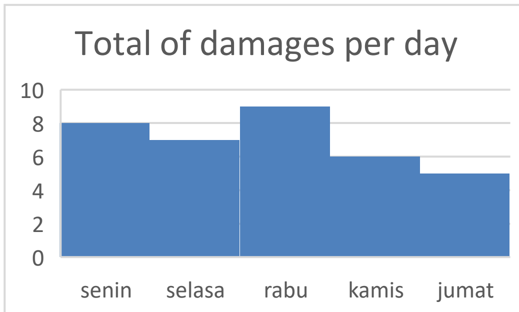

Figure 2 diagram of the amount of damage

Determining factor levels

The level setting is determined by considering the company's current operational limitations and potential changes to ensure the test results are as realistic as possible. The level settings specified for each control factor are described below.

Table 2 Design Variables

Design Variable	Variations		
	Level 1	**Level 2**	**Level 3**
Cable diameter	1 mm	2,5 mm	3 mm
Types of socket sizes	4 pin holes medium socket type	6 large socket-type pin holes	3 small socket type pin holes
Cable length	2 meters	3 meters	1 meter
Waktu wiring	15 minutes	25 minutes	10 minutes

Determination of orthogonal array matrix

The determination of the orthogonal array (OA) matrix in the Taguchi method is one of the important steps in the experimental design process (Mensah et al., 2019). OA is used to determine the level combination of factors to be tested. Table 4 is a calculation of the degree of freedom of control factors in this study. This experiment uses four factors in a three-level design. The number of columns in an orthogonal matrix can be determined from the number of levels and factors present. Using orthogonal array matrix analysis, the orthogonal array calculation is obtained as follows:

Table 3 alculation of the degree of freedom of the orthogonal matrix Array

Code	Factor	
	Explanation	DF
A	Cable Diameter	(3-1)

B	Types of socket sizes	(3-1)
C	Cable length	(3-1)
D	Wiring time	(3-1)
	Total	8

From the calculation table above, it can be seen that the factor of this writing is eight (8) To find the degree of freedom of the orthogonal array, multiply the degree of freedom of each column by the number of columns. Based on the explanation in Table 8 This study should have been carried out with an orthogonal arrangement =, but because the Taguchi experiment did not show its existence, the number of orthogonal arrangements required was increased to = to carry out the research according to Taguchi's rules as illustrated in the Table below $L_8 3^4 L_9 3^4$:

Table 4 Standard orthogonal array matrix from taguchi

2 Level	3 Level	4 Level	5 Level	Level gabungan
$L_4(2^3)$	$L_9(3^4)$	$L_{16}(4^5)$	$L_{23}(5^6)$	$L_{18}(2^1x3^7)$
$L_8(2^7)$	$L_{27}(3^{11})$	$L_{64}(4^{21})$		$L_{32}(2^1x3^9)$
$L_{12}(2^{11})$	$L_{81}(3^{40})$			$L_{36}(2^{11}x3^{12})$
$L_{15}(2^{15})$				$L_{36}(2^3x3^{13})$
$L_{32}(2^{31})$				$L_{54}(2^1x3^{23})$

Source: (Gao, Xu, and Xu 2022)

Implementation of Taguchi's Design of Experiment (DOE) Calculation

It is carried out based on the results of calculating the degree of freedom. The result of the calculation is that the orthogonal matrix used in this experiment is =. While the experimental data are $L_9 3^4$:

Table 5 Taguchi Design of Experiment (DOE) Calculation

Eksperimen	Control Factors				Result		
	A	B	C	D	I	II	III
1	1	1	1	1	1.15	0.04	0.02
2	1	2	2	2	1.25	0.06	0.03
3	1	3	3	3	1.10	0.03	0.01
4	2	1	2	3	2.10	0.04	0.03
5	2	2	3	1	2.15	0.06	0.01
6	2	3	1	2	2.25	0.03	0.02
7	3	1	3	2	3.25	0.04	0.01
8	3	2	1	3	3.10	0.06	0.02
9	3	3	2	1	3.15	0.03	0.03

The number of rows indicates the number of experiments performed. This experiment was repeated three times (repeated experiments), so it required a total of 9 attempts to be carried out. The level code and its value are shown in table 5. From the calculation using the equation, the average and SNR tables from the 1st to the 9th data are obtained as follows:

Table 6 Average $\bar{y}$ and SNR

No	Y1	Y2	Y3	mean	$S/N - 10\log\left(\frac{1}{3}\sum_{i}^{3} = \frac{1}{y1^2}\right)$
1	1,15	0,04	0,02	0,4033333	30,17
2	1,25	0,06	0,03	0,4466667	26,65
3	1,10	0,03	0,01	0,38	35,68
4	2,10	0,04	0,03	0,7233333	27,62
5	2,15	0,06	0,01	0,74	35,34
6	2,25	0,03	0,02	0,7666667	30,8
7	3,25	0,04	0,01	1,1	35,49
8	3,10	0,06	0,02	1,06	29,66
9	3,15	0,03	0,03	1,07	28,69

The data above will be analyzed in four ways: calculating the effect of the mean, calculating the SNR effect and calculating for each replication, and calculating the variant analysis (ANOVA). Calculating the average impact of these factors is done by subtracting the average of the largest responses from the average of the largest responses. The results of the calculation of the average influence value and the influence value of each factor are obtained in Table 6.

Table 7 Response Table for Means

Level	Cable diameter	Socket Type	Cable Length	Wiring time
1	0,4100	0,7422	0,7443	0,7378
2	0,7433	0,7489	0,7467	0,7711
3	1,0767	0,7389	0,7400	0,7211
Delta	0,6667	0,0100	0,0067	0,0500
Rank	1	3	4	2

Calculation of the effect of SNR

The calculation of the effect of SNR on factors is done by subtracting the average value of the largest response from the average value of the largest response. So that the average response value and SNR effect value are obtained in the table below:

Table 8 Calculation of the effects of SNR

Level	Cable diameter	Socket Type	Cable Length	Wiring time
1	-4,085	-4,338	-4,341	-4,326
2	-4,392	-4,421	-4,239	-4,302
3	-4,511	-4,214	-4,409	-4,360
Delta	0,426	-4,437	0,170	0,058
Rank	1	3	4	2

Calculate the effect of each factor for each replication

The first step of this calculation is to find the average response of each factor level for each replication. The calculation of the response for each level of each factor using the equation from the calculation using the equation above, the response table of each factor for each replication is obtained as follows:

Table 9 Calculation of the effect of each factor for each replication

Factor	Y1	Y2	Y3	Rangking
A1	30,83	31,25	31,28	1
B1	31,09	30,55	30,55	3
C1	30,21	27,65	27,65	4
D1	31,4	30,98	30,98	2

S/N Prediction		S/N Exiting	
Parameter	S/N	Parameter	S/N
Average S/N	31,12	Average S/N	31,12
A1/A2/A3	31,28	A1	30,83
B1/B2/B3	31,72	B2	30,55
C1/C2/C3	35,5	C2	27,65
D1/D2/D3	31,4	D2	30,98
Total	36,54	total	26,65

Prediction	
Exiting Design	26,65
Optimum Design	36,54
gain	9,89

From the calculation of the average response to the replication, we can determine the effect of each factor for each replication, namely by subtracting the average value of the largest response by the average value of the smallest response.

ANOVA variant analysis calculation

From the data of the experiment results to find out the contribution of each controlled factor, then a variant analysis was carried out with the following calculation results:

Table 10 Analysis of Variance

Source	DF	Sum Square	%	Adj SS	Mean Square	F-Value	P-Value
A	2	2,0000	5,99%	2,0000	1,00000	0,57	0,573
B	2	0,0005	0,00%	0,0005	0,00023	0,00	1,000
C	2	0,0002	0,00%	0,0002	0,00010	0,00	1,000
D	2	0,0117	0,03%	0,0117	0,00583	0,00	0,997
Error	18	31,3765	93,97%	31,3765	1,74314		
Total	26	33,3888	100,00%				

Table 10 provides a comparative summary of the four calculation methods that have been carried out. So that a ranking table of the influence of each factor can be obtained as follows:

Table 11 Ranking of the Influence of Each Factor

Rangking	Mean	SNR	Repikasi	Anova
1	A	A	A	A
2	D	B	D	D
3	B	C	B	B
4	C	D	C	C

From Table 11 ANOVA above shows that by comparing the f-value of each factor and interaction with a value of 0.05, we can find out the factors or interactions that significantly influence the defect rate in the electric motor assembly line. If the f-value of the factor or interaction is more than 0.05, then it can be concluded that the factor or interaction has a significant influence on the response variable .

Conclusion

As a result of the report and the data processing process, several conclusions can be made: We can see the largest error rate in the production process from Table 13 of ANOVA by comparing the f-value of each factor and interaction with the value of 0.05, we can find out the factors or interactions that have a significant influence on the rate of defects in the assembly of electric motors that occur in electric motor cables. The types of defects that are produced from the assembly process are often found in socket products and pin cables on sockets that are detached from the housing. The pin bit is not connected to the cable or the pin eye is separated from the socket housing which is caused by negligence during the process when checking the electrical cable. The quality of the electrical socket decreases due to the long delivery process and is not properly placed so that it experiences an impact.

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