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Improving the Quality of Brake Lining Production of Non-Asbestos 2 (NA2) Type Using Six Sigma Method

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Abstract

Currently, Indonesia's manufacturing sector is expanding at a respectable rate. This encourages business owners to focus on the quality of their products. Good production standards will result in high-quality items. A consumer-satisfying product can enhance the company's sales. This study was conducted in a plant that has produced brake linings exclusively since 2002. Cracks and bloating faults are still present on the surface of the brake linings at this manufacturer; therefore, changes are necessary. The goal of this study was to identify the types of defects, quantify the degree of faults, identify and analyze the variables generating defects, and make recommendations for improving the quality of the company's brake lining manufacture. As evaluated by the sigma value, the current production quality of the Non-Asbestos 2 (NA2) type brake lining is 3.93 sigma. Utilizing the phases of define, measure, analysis, improve, and control, six sigma's is employed (DMAIC). This study's outcomes include proposed enhancements and comparisons of sigma values before and after implementation. The conclusion of this study is that there are two types of defects, namely cracks and bloating, resulting from of a number of factors. Standard operating procedures (SOP), checklists, standard forms for measuring raw materials, and investment in more advanced machines are proposed as means of improvement. The implementation findings yielded a sigma value of 4.59 (an increase of 0.66 sigma from before).

Keywords
Brake Lining, Defect, DMAIC, Quality, and Six Sigma

1. Introduction

Currently, the manufacturing industry in Indonesia is increasing at a decent rate. This expansion resulted in the formation of numerous manufacturing enterprises, which intensified commercial competition. This motivates business owners to focus on product quality to satisfy client demands. There are seven types of waste that arise in the industrial process. Waste of overproduction, inventory, defects, transportation, motion, waiting, and over processing are the seven wastes (Sari, 2018). This level of waste must be decreased in the production process, if not, it will impede the production process and prevent efficient output. PT. Indolining was established in 2002 and specialized in the production of brake linings. Brake lining serves as a barrier to friction between two iron plates, notably the brake shoe and brake drum, in order to lower braking speed and stop the rotation of the car's tires. The brake linings produced also have several types of products including types CP, CP3, 51 HS, Non Asbest (NA), Non Asbest 2 (NA2), Non Asbest Australia (NA Australia) and TVS. PT. Indolining has a quality control staff, although quality control is confined to the operator physically inspecting items for defects. If a product is damaged, for instance, employees will determine whether it can still be repaired; if it cannot be repaired, it will be destroyed and reprocessed. In producing brake lining at PT. Indolining has waste that occurs, namely defects, where defective products are found in their production. Table 1 contains information on product defects.

Table 1. Data on total production and defective brake lining products

Month	Type	Production Quantity (Pcs)	Defective Products (Pcs)	Percentage of Defect (%)
January	CP	35,740	253	0.71
	C3	544	1	0.18

Month	Type	Production Quantity (Pcs)	Defective Products (Pcs)	Percentage of Defect (%)
	51 HS	2,792	49	1.76
	NA	-	-	-
	NA2	4.108	107	2.60
	NA Australia	-	-	-
	TVS	330	0	0.00
February	CP	31.126	156	0.50
	C3	2.203	2	0.09
	51 HS	2.011	7	0.35
	NA	64		0.00
	NA2	2.506	30	1.20
	NA Australia	-	-	-
	TVS	120	0	0.00
March	CP	35,729	184	0.51
	C3	9.332	54	0.58
	51 HS	2,460	8	0.33
	NA	-	-	-
	NA2	1.457	32	2.20
	NA Australia	256	0	0.00
	TVS	281	0	0.00
April	CP	31,758	128	0.40
	C3	7.461	40	0.54
	51 HS	1.420	8	0.56
	NA	-	-	-
	NA2	4,998	41	0.82
	NA Australia	1.204	41	3.41
	TVS	810	0	0.00
May	CP	20.914	142	0.68
	C3	4.595	1	0.02
	51 HS	1,590	14	0.88
	NA	-	-	-
	NA2	1.735	10	0.58
	NA Australia	676	1	0.15
	TVS	289	6	2.08
June	CP	35,774	81	0.23
	C3	6,400	17	0.27
	51 HS	1.480	17	1,15
	NA	-	-	-
	NA2	1.361	21	1,54
	NA Australia	240	1	0,42
	TVS	335	5	1,49

Table 1 reveals that NA2 brake lining production has the greatest average number of defects, at 1.49 percent; therefore, the focus of the research is on enhancing the production process for NA2 brake linings. The current DPMO value for NA2 type brake lining manufacture is 7,454 with a Sigma value of 3.93. There are no company-wide guidelines for identifying problems that are acceptable. Nonetheless, this research aims to improve the quality of output. In this instance, the Six Sigma method is utilized to reduce the defect rate and enhance manufacturing quality. Six sigma is a methodology that employs a set of strategies and tools to improve the quality of a product or service by identifying and reducing or eliminating the causes of defects and by limiting process variability (Brue, 2015). Utilizing the Define, Measure, Assurance, Improvement, and Control (DMAIC) cycle, Six Sigma is implemented (Soemohadiwidjojo, 2017). Define, which includes developing a system, recording client voices and wants, and establishing clear goals to be attained. Measure performance of ongoing processes and collect pertinent data. Analyze, refers to the process of examining acquired data for relationships in order to determine the underlying cause of faults. Improve the

performance of the process by identifying and eliminating the root causes. The control stage is intended to ensure that the enhanced process provides the expected objectives (Syarief and Kartini, 2018).

2. Literature Review

To win the competition, quality is required and plays a vital role. Satisfaction of consumer wants, conformity to set standards/benchmarks, and affordable costs are the three basic components of quality (Walujo and Utomo, 2020). The fundamental premise of Six Sigma is enhancing the quality of a product by enhancing the process so that it generates a flawless result. Six Sigma is focused on long-term performance via quality improvement to reduce the amount of errors, with a goal of zero failure (zero defects) in process capabilities equivalent to or more than 6-sigma in measuring standard deviation. With a standard deviation of 99,999.97% from the desired target value, the probability of failure or a defective product at the 6-sigma level is comparable to 3.4 defects per million opportunities (DPMO). This manufacturer produces defective brake linings, particularly the NA2 type, which has the highest percentage of overall defects among all brake lining types, at 1.49 percent. This product defect disturbs the manufacturing process because, based on the observations, the defective product must be rectified, and if it cannot be repaired, it must be destroyed and reprocessed, hence increasing production time. Determining the types of defects in the NA2 type brake lining through observation, measuring the level of defects in the NA2 type brake lining with the P-control map for the proportion of defects and calculating DPMO so as to find the Sigma value, identifying and analyzing the factors causing defects using Failure Mode Effect Analysis (FMEA), and providing suggestions for improvement to improvise.

3. Methods

The following is the research method conducted at PT. Indolining can be seen in Figure 1.

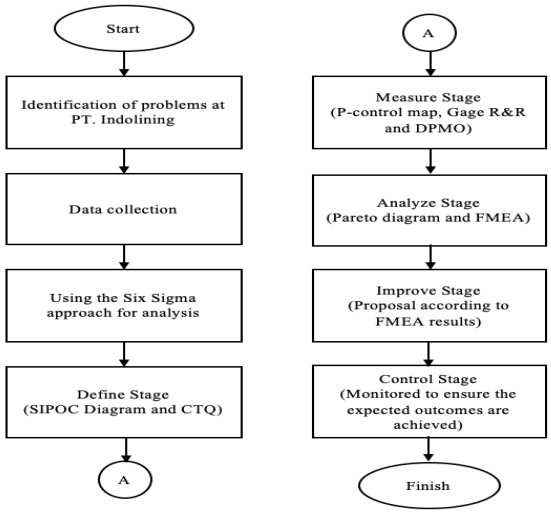


Figure 1. Research methodology

4. Data Collection

Utilizing historical data collected from January 2021 to June 2021, the amount of production defects in brake linings during that time period can be determined. This data was obtained from Microsoft Excel which was given by the manager of the PPIC section of PT. Indolining. Interviews were conducted with PPIC managers, PPIC staff and field staff both offline and online, to complete and obtain more detailed information for the research. Observations were carried out directly on the production floor to see how the brake lining is made to know the time it takes to make the brake lining, to see the working conditions, to see how the field staff work and to see firsthand the defects in the brake lining.

5. Results and Discussion

After collecting the necessary data, the research is conducted through the phases of Define, Measure, Analysis, Improve and Control (DMAIC).

5.1 Define Stage

During the beginning phase of the DMAIC process, it is necessary to define and identify the most critical challenges. The SIPOC diagram is used to explain the relationship between a business process' suppliers, inputs, processes, outputs, and consumers (Wawan et al., 2017). Figure 2 displays the business's SIPOC diagram.

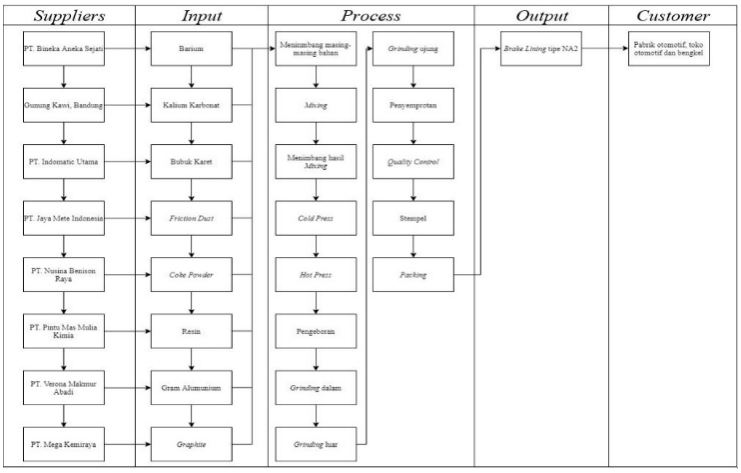


Figure 2. SIPOC diagram of PT. Indolining

Critical to Quality (CTQ) is a regularly employed method for quantifying and simplifying complex customer requirements (Suwandi, 2020). Figure 3 depicts the brake lining used for CTQ brakes.

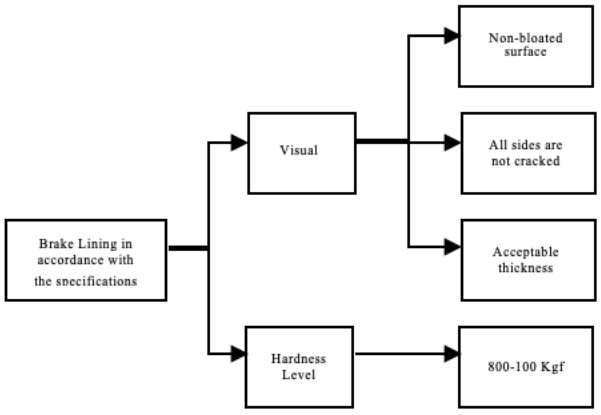


Figure 3. CTQ of Brake Lining

5.2 Measure Stage

At this step, performance measurement is performed on the ongoing process and pertinent data is collected. The P-control map is used to establish whether a process is stable and predictable, as well as to monitor the process improvement theory's effectiveness (Mathile, 2021). Figure 4 depicts the P-control map of the NA2 type brake lining for the period January 2021 to June 2021.

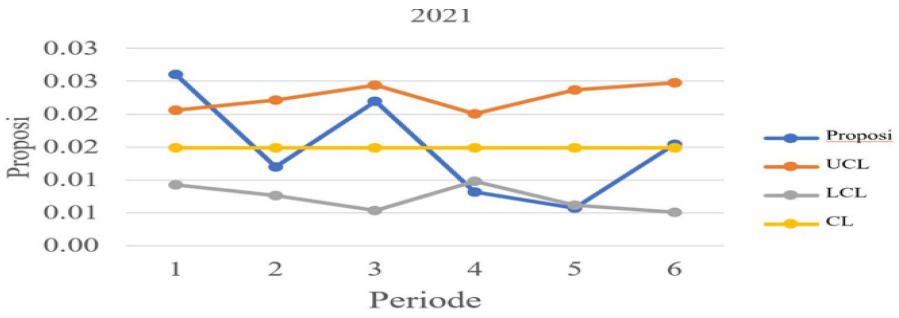


Figure 4. P control map for the period January 2021 to June 2021

• Defects Per Million Opportunities (DPMO)

In a Six Sigma quality improvement program, DPMO is a measure of failure that measures failures per million opportunities. Six Sigma quality control aims to attain a DPMO of 3.40 (Gasperz, 2002)

$$DPMO = \frac{D}{U*O} * 1.000.000 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Which:

D = Total number of defects, U = Number of units, O = number of opportunities that will result in defects (opportunities)

$$DPMO = \frac{241}{16.165 * 2} * 1.000.000 = 7{,}454{,}376$$

According to the DPMO's calculations, there are 7,454,376 defects for every million possible outcomes. Using a six-sigma calculator, the company's Sigma value for the manufacturing of brake lining type NA2 is 3.93 Sigma, indicating that there is still room for production quality improvement.

• Gage R&R

To calculate the R&R % of GRR to determine the viability of the company's measurements to make brake lining type NA2, use the following formula:

$$\%GRR = \frac{GRR}{TV} * 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

$$\%\ \text{GRR} = \frac{0{,}186}{0{,}808} * 100 = 23.01\%$$

The following guidelines from the book (Mikel, 2010) are used to determine whether the measurement system is acceptable: 1. < 10 percent = Acceptable measurement system.

Based on the significance of the application, the cost of measurement tools, repair costs, etc., 10% to 30% is acceptable. Greater than thirty percent is deemed unsatisfactory; the measurement system must be improved.

As a consequence, because the GRR result is 23.01 percent, the measurement system used by the operator at PT. Indolining to make brake line type NA2 may still be allowed based on the application.

5.3 Analyze Stage

At this stage, the collected data is analyzed to determine the causes and effects of product faults by identifying correlations between the data. A Pareto chart is a bar graph that ranks the frequency of occurrences of problems. To generate a Pareto diagram, data like Table 2 are required.

Table 2. Percentage of types of defects of brake lining type NA2

Type of Defect	Quantity (Pcs)	Percentage (%)	Cumulative Percentage (%)
Bloating Defect	48	19.91	19.91
Crack Defect	193	80.09	80.09
Total	241	100	100

Figure 5 depicts the Pareto brake lining diagram for Type NA2 vehicles.

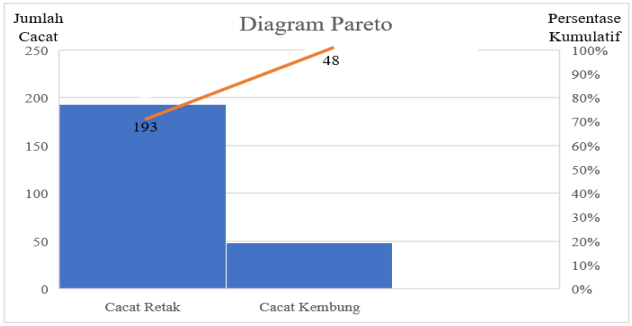


Figure 5. Pareto brake lining diagram for Type NA2 vehicles

- **Failure Mode Effect Analysis (FMEA)**

FMEA is the process of detecting numerous potential manufacturing faults that can be produced by equipment, workers, materials, procedures, or work circles (Walujo, 2010). Table 3 displays the FMEA for the NA2-type brake lining manufacturing process.

Table 3. FMEA brake lining type NA2

No	Potential Failure Mode	Effect of Failure	Cause of Failure	Current Process Control	S	O	D	RPN	Rank	Action Recommended
1	Crack Defect	It can break when utilized	Improper material formulation	Formula revision	8	9	5	360	1	Establishing standard formulas for each type of brake lining
			Improper temperature control	Reset temperature such that it is neither too high nor too low	8	6	6	288	2	Checklist of raw materials and implementation of SOP for operation of a hot press machine
			Varied outcomes for each operator's hardness tests	Manual re-measurement	8	5	5	200	3	Calibrate a hardness tester on a regular basis or invest in a digital machine.
2	Bloating Defect	Can be separated from the brake shoe	Improper temperature control	Reset temperature such that it is neither too high nor too low.	8	6	6	288	2	Checklist of raw materials and implementation of SOP for operation of a hot press machine

5.4 Improve Stage

There are various proposals for improvement in this study, including the proposed table form of the standard formula, which serves to standardize the standard formula for NA2-type brake lining. The proposed raw material checklist, in this case the raw material checklist, is utilized to determine which raw materials can be utilized in compliance with the raw material quality specification. Third, the proposed standard operating procedure (SOP) for the operation of the hot press machine, because no soup was previously provided to the operator, so the operator must pay closer attention to the steps for operating the hot press machine after the raw materials with the specified quality have been deemed feasible and can control temperature properly. Fourth, the projected investment in more sophisticated testing devices; as the prior machine was a manual hardness measuring instrument, a Brinell Digital Hardness Tester is required to produce more accurate measurement results. For instance, the Brinell Digital Hardness Tester of the Zonhow brand, model LHB-3000A, is appropriate for the brake lining hardness test due to its exceptionally high load capacity of up to 3000 Kgf. This device costs approximately $2,750. (based on the price listed on alibaba.com). Fifth, the idea to increase the quality test, the PT-performed quality test phase. The current PT. Indolining procedure for the completed brake lining is a hardness test utilizing a hardness tester. Therefore, it is required to include a quality test for the brake lining, namely the abrasive wear test, as it is also necessary to assess the brake lining's resistance to friction in addition to its hardness. This test may be conducted using a Dongguan Hongtuo DH-TA-01 abrasion tester machine. This gadget costs between $1,000 and $1,999 (based on the price listed on hongtuoinstrument.en.made-in-china.com). This abrasive wear test is conducted by taking many production samples.

5.4 Control Stage

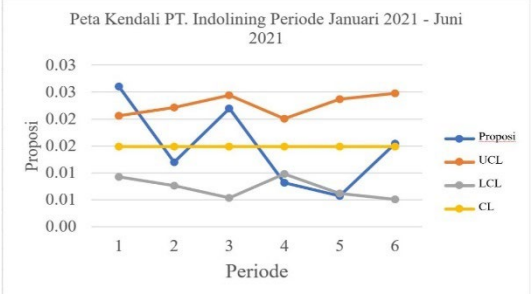
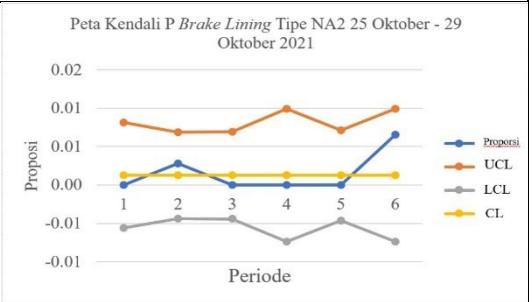
At the control stage, processes that have been optimized are monitored to ensure that the desired results are obtained. Three out of the five recommended improvements can still be accomplished. These include the proposed standard formula table format, the proposed checklist for the quality of raw materials, and the suggested standard operating procedure (SOP) for the operation of the hot press machine. Table 4 provides information regarding the number of defective and non-defective NA2 type brake linings produced throughout implementation. Table 4 explained data on number of production and defective products of brake lining type NA2 on October 25 – 30, 2021

Table 4. Data on number of production and defective products of brake lining type NA2 after implementation

Date/Day	Number of Production (Units)	Defective Product (Unit)
25/Monday	240	0
26/Tuesday	359	1
27/Wednesday	352	0
28/Thursday	152	0
29/Friday	328	0
30/Saturday	152	1
Amount	1.015	2

Following is a comparison of the production quality of brake linings before and after the implementation of the proposed improvement, as measured by three indicators: P control chart, DPMO value, and Sigma value. As seen in Table 5.

Table 5. Comparison of Production Quality Before and After Implementation

Indicator	Before	After
P Control Map		
DPMO	7,454,376	985,2217

Sigma Value	3.93	4.59

Based on the comparison of control chart P, it can be seen that numerous productions were still outside the control limits in the first, fourth, and fifth months prior to implementation. However, after implementation, the proportion of defective brake linings of type NA2 remains within the control limits. Prior to the implementation of the proposed enhancement, the DPMO value was 7,454,376 with a Sigma value of 3.93 Sigma. In contrast, the DPMO value is 985.2217 with a Sigma value of 4.59 after the execution of the proposed enhancement. By increasing the Sigma value during the production of NA2-type brake linings, it is evident that the proposed change has a positive effect on production quality. According to the findings of interviews with Mr. Abdul, a member of the production floor crew, and Mr. Onggo, the production manager, the availability of a number of proposed changes is sufficient to assist staff or operators with the production process. The existence of a raw material dosage form clarifies the raw material dosage form for personnel. In addition, the existence of a checklist for the quality of raw materials aids personnel in controlling the quality of raw materials, and standard operating procedures for hot press machines aid personnel in operating hot press machines with greater care.

6. Conclusion

In the production of brake linings of the NA2 type, there are two primary categories of faults. The two forms of problems are brake lining surface swelling and brake lining surface cracking. During the production of NA2-type brake lining, a number of reasons contribute to the product's deficiency, including improper material composition, improper temperature management, and varying operator hardness test results. There are a number of suggestions for overcoming the issues that lead to the product's deficiency, including the proposed standard formula table form, the proposed checklist for the quality of raw materials, the proposed standard operating procedure (SOP) for the operation of the hot press machine, and the proposed investment for a more advanced measuring instrument, namely Brinell Digital. Hardness Tester Zonhow model LHB-3000A, with the proposed addition of an abrasive wear quality test using the Dongguan Hongtuo model DH-TA-01 abrasion testing equipment.

The DPMO value for the manufacture of brake lining type NA2 from January to June 2021 is 7,454,376 with a sigma value of 3.93 sigma. With these figures, the NA2 type brake lining manufacture quality can still be enhanced. After implementing the recommended enhancement, the DPMO value reduced to 985.2217, resulting in an increase in the sigma value to 4.59. This demonstrates that the proposed enhancement has a positive effect on production quality. In addition to the conclusion, the company can also be given the following recommendations for producing the NA2 type brake lining: considering the proposed improvement to purchase a Brinell Digital Hardness Tester machine so that measurement results between operators are more accurate and feasible; and considering the proposed improvement. Purchase the Dongguan Hongtuo Abrasion Testing Machining machine, type DH-TA-01, to add to the abrasive wear quality test. If the standard is decided by the hardness test, it is judged insufficient, so the NA2 type brake lining product requires an additional test, namely the abrasive wear test.

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