Six Sigma as Quality Improvement: An Insight from Disc Front Brake Manufacturing

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Abstract

This study investigates the applicability of the Six Sigma technique to the automotive industry's disc front brake production process. The study applies the DMAIC (Define, Measure, Analyze, Improve, and Control) methodology to identify and repair flaws in the production process, hence boosting product quality and minimizing defects and process irregularities. Using statistical analysis and Six Sigma technologies, the inquiry aims to determine the critical process parameters influencing product quality in partnership with significant manufacturing facilities. The anticipated results include a reduction in faults, an increase in process stability, potential cost savings, and an improvement in vehicle safety. This study focuses on improving the quality and efficiency of production processes, and it examines the most recent technological developments and advancements in the automobile industry. The research findings reveal a rejection rate of 3.45 percent, with various rejection categories including dents, "Goyang," "Getar," diameter inconsistencies, and steps. These rejections are caused by a variety of factors, including dirty reference points, material impacts, and inadequate adhesion in cases of misalignments. Additional suggestions for reducing rejects include the implementation of training programs, documentation, the establishment of new Standard Operating Procedures (SOPs), the creation of machine maintenance checklists, the scheduling of coolant box drainage, the adoption of new target setting cycles, and the utilization of checklists as control measures.

Keywords: Disc Front Brakes, Six Sigma Methodology, DMAIC, Quality Assurance, Process Improvement

1. Introduction

The automotive industry is proof of human determination to achieve engineering excellence, where safety and performance are interrelated as the primary concerns in every product produced. At the center of this complex ecosystem lies the manufacturing process of critical components, none more vital than front disc brakes. The effectiveness of this braking system is not only a matter of engineering precision but also a matter of non-negotiable quality assurance. In this context, the Six Sigma Methodology is emerging as a highly effective tool, offering a structured approach to identify and eliminate variations in manufacturing processes, thus paving the way for improved levels of product quality.

Initially conceptualized by Motorola in the 1980s, Six Sigma evolved into a global standard for process improvement, finding application in various industries, from healthcare to electronics manufacturing (1,2). Its core principles, rooted in data-driven decision-making, place it as a valuable tool in pursuing manufacturing excellence. By carefully defining, measuring, analyzing, improving, and controlling processes (DMAIC), Six Sigma empowers organizations to improve quality while systematically minimizing process defects and variations(3,4).

This research begins an exploration of the focus on Six Sigma applicability in disc front brake manufacturing. This domain requires accurate precision to ensure optimal performance and, more critically, the safety of millions of vehicles worldwide. By applying the Six Sigma methodology to this critical juncture of automotive production, the potential for profound quality improvements and operational efficiency is sought to be uncovered. Disc front brake manufacturing, characterized by complex processes, poses unique challenges regarding consistency, reliability, and cost-effectiveness. Variations in material properties, machining tolerances, and assembly procedures can cause deviations in performance, requiring a careful approach to quality control. Through this research, an effort is made to illuminate the subtle interplay between Six Sigma principles and the multifaceted intricacies of disc brake production. The research adopts a case study approach in collaboration with leading disc brake manufacturing facilities to achieve this goal. Critical process parameters that affect product quality are identified through rigorous data collection, statistical analysis, and the application of Six Sigma tools by examining the tangible results of this implementation, including defect reduction, improved process stability, and cost savings, to support the benefits of Six Sigma integration into the disc front brake manufacturing process.

Furthermore, the study explores the organizational implications of Six Sigma adoption, emphasizing the need for a culture of continuous improvement and the development of cross-functional teams proficient in Six Sigma methodology. Addressing these strategic considerations can provide a holistic view of the transformational potential of Six Sigma in the context of disc front brake manufacturing. This study bridges automotive engineering and quality assurance domains through the Six Sigma methodology. Explaining its principles, contextualizing its application, and supporting its impact is expected to contribute to a comprehensive understanding of how Six Sigma can serve as a driver for raising quality standards in disc front brake manufacturing.

2. Literatur Review

Six Sigma is a quality improvement method that minimizes process errors and reduces product defects(5). Six Sigma is one technique to control product quality, improve quality, and reduce defects to close to 3.4 per million opportunities (6). Six Sigma implements statistical science with an accuracy rate of 99.9997% (7). Definition, measurement, analysis, improvement, and control are different stages aiming to identify defects and their root causes (8). Coordination between system components is the main success factor in every improvement effort (9), including applying the Six Sigma method.

Six Sigma has been widely used to improve the quality of processes and products in various industrial sectors, including manufacturing. Several studies capture applications in the field; Srinivas & Sreedharan (2018) research identifies crucial problems in automotive parts distribution centers, where even though automotive components are not subject to processing, various distribution operations contribute to component failure. Six Sigma DMAIC methods are used effectively to analyze failures. Various rejection causes are generated through cause-and-effect diagrams, and each of these causes is validated through experiments and other tools. The root cause of the problem is identified as the packaging method. Economical solutions are applied with minor variations on packaging methods. Although it provides a practical solution, the case study found that this method requires additional time and resources and may create resistance from the production team to process changes. Trimarjoko et al. (2019) and Gupta et al. (2018) use Six Sigma in the Tire industry. Gargate et al. (2019) Using Six Sigma reduces truck fleet downtime and increases open-pit mining operations' productivity. The case study results show that selecting the optimal fleet appropriate to the conditions of a particular mining project resulted in significant improvements in productivity and efficiency. This is reflected in the more effective use of machines and reduced unproductive time. Six Sigma in the foundry industry (14–17). However, it should be noted that although various aspects of casting defects have been investigated, no studies have specifically addressed defects that may occur in machining processes in the metal casting industry using the Six Sigma method approach.

3. Result and Discussion

At this stage, the results and discussion will be described into several stages with the following results:

3.1 Define

The first stage in applying the Six Sigma method is defined. At this stage, data collection activities are carried out to identify key quality characteristics with *Critical To Quality (CTQ)* following customers' wishes, identify the type of product reject, and determine the number of product rejections. The data used in the study were collected in 2022. The identification results can be seen in the table below (Table 1).

Tabel 1 Critical to Quality produk disc front brake

CTQ	Specifications	Information	Reject Type
Dimension	$d1 = 65^{+0.04}_{-0}$ mm $Z1 = 25^{+0.1}_{-0.02}$ mm $d2 = 5{\sim}\emptyset 8.7 \pm 0.1$ mm $T1 = 5{\sim}M10x1.25$ mm	The product must not be out of dimension beyond the product specifications requested by the customer.	Dimension +/-
Visual	The field yield of the machining process should be flat.	The surface of the machining plane must have no *dents,* vibrations, or steps.	1. *Dent* 2. Getar 3. Step
Round Balance	The maximum weight difference limit is 100 g/cm^3	The product has a weight that rests on one point.	Goyang

Table 1 above shows that disc front brake products have three critical qualities: particular specifications desired. The specifications are dimensions, visuals, and rotation balance with the rejection types. Next is to identify the amount of production, the type of reject product, and the number of reject products.

Tabel 2 disc front brake production data.

Moon	Production Quantity	Reject Type					Total reject	Percentage of number of rejects
		Diameter +/-	Getar	Step	Dent	Goyang		
January	14.418	74	90	116	321	292	893	6,19%
February	13.812	112	32	0	170	47	361	2,61%
March	14.048	45	53	86	191	159	534	3,80%
April	14.418	9	47	60	201	97	414	2,87%
May	12.004	62	59	32	232	183	568	4,73%
June	14.108	0	6	0	181	154	341	2,42%
July	14.048	29	40	17	167	103	356	2,53%
August	12.380	34	72	32	179	138	455	3,68%
September	13.804	47	56	4	190	176	473	3,43%
October	12.818	23	58	11	175	129	396	3,09%
November	12.602	94	107	44	229	190	664	5,27%
December	11.344	0	1	0	33	22	56	0,49%
Sum	**159.804**	**529**	**621**	**402**	**2.269**	**1.690**	**5.511**	

Table 2 above shows that the number of disk front brake products produced during 2022 is 159,804 Pcs, with the number of defects reaching 5511 Pcs (about 3,45% reject rates). Several design defects occur, such as +/- diameter, *Getar*, step, dent, and *goyang*. In one year, as many as 11 months exceed the reject standard limit set by the company, which is 0.5%. Only one month has a percentage of rejection below the standard reject limit.

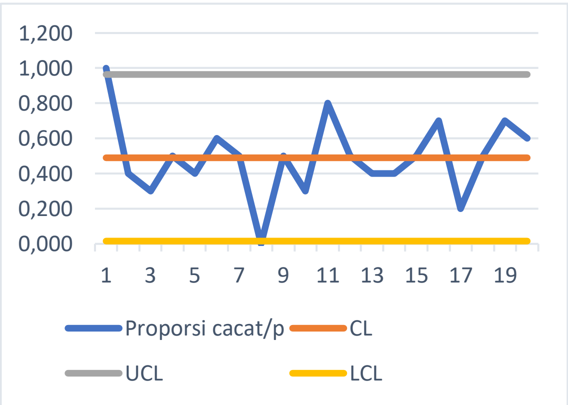
3.2 Measure

The second stage is the measure stage. Several main actions can be done: creating a control map of attributes and variables, calculating process capabilities, and implementing a Pareto diagram. Next, calculate the DPMO and sigma value to determine the process capability of the company.

Table 3 Attribute control map before revision

NO	Sample data (n)	Data defect (NP)	Proportion of defects (p)	CL	UCL	LCL
1	10	10	1,000	0,490	0,964	0,016
2	10	4	0,400	0,490	0,964	0,016
3	10	3	0,300	0,490	0,964	0,016
4	10	5	0,500	0,490	0,964	0,016
5	10	4	0,400	0,490	0,964	0,016
6	10	6	0,600	0,490	0,964	0,016
7	10	5	0,500	0,490	0,964	0,016
8	10	0	0,000	0,490	0,964	0,016
9	10	5	0,500	0,490	0,964	0,016
10	10	3	0,300	0,490	0,964	0,016
11	10	8	0,800	0,490	0,964	0,016
12	10	5	0,500	0,490	0,964	0,016
13	10	4	0,400	0,490	0,964	0,016
14	10	4	0,400	0,490	0,964	0,016
15	10	5	0,500	0,490	0,964	0,016
16	10	7	0,700	0,490	0,964	0,016
17	10	2	0,200	0,490	0,964	0,016
18	10	5	0,500	0,490	0,964	0,016
19	10	7	0,700	0,490	0,964	0,016
20	10	6	0,600	0,490	0,964	0,016
Sum	200	98				
p-bar	0,490					

Table 3 above is observational data collected 20 times with 10 product samples. Total rejections reached 98 pcs of products from 200 sampled products.



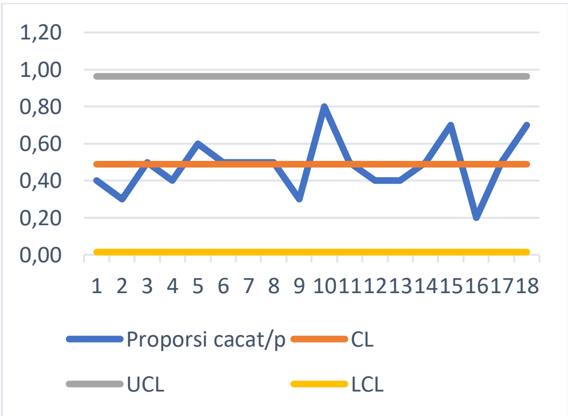


Figure 11   22

Figure 1 shows that two proportions of rejected products still exceed the UCL and LCL limits, so there needs to be improvements on the control map so that the proportion of rejected products is within the UCL and LCL vulnerabilities, which is between 1.6% and 96.4%. Figure 2 shows that the proportion of rejected products is already within the UCL and LCL limit ranges.

The first peer-made variable control map is a variable control map of reject *goyang* with the following data and results:

Table 4 Control data X rejects *Goyang* before revision

Sample	$\bar{X}$	*Range*	*CL*	*LCL*	*UCL*	*Sample*	$\bar{X}$	*Range*	*CL*	*LCL*	*UCL*
1	94,3	62	67,14	41,73	92,55	**12**	93,4	53	67,14	41,73	92,55
2	64	90	67,14	41,73	92,55	**13**	58,6	92	67,14	41,73	92,55
3	61,2	84	67,14	41,73	92,55	**14**	38,2	43	67,14	41,73	92,55
4	62,9	95	67,14	41,73	92,55	**15**	55,3	92	67,14	41,73	92,55

Sample	$\overline{X}$	Range	CL	LCL	UCL	Sample	$\overline{X}$	Range	CL	LCL	UCL
5	54,2	86	67,14	41,73	92,55	**16**	79	88	67,14	41,73	92,55
6	67,6	94	67,14	41,73	92,55	**17**	69,8	69	67,14	41,73	92,55
7	56,8	86	67,14	41,73	92,55	**18**	72,2	90	67,14	41,73	92,55
8	64,3	71	67,14	41,73	92,55	**19**	93,9	118	67,14	41,73	92,55
9	62,3	80	67,14	41,73	92,55	**20**	75,5	83	67,14	41,73	92,55
10	55	91	67,14	41,73	92,55	Sum	1342,7	1650			
11	64,2	83	67,14	41,73	92,55	X Bar	67,135	82,5			

From Table 4 of the control map of the shake reject variable above, it is known that the average of the balancing results is $67{,}135\ \mathrm{gr/cm^3}$with a UCL limit value of and an LCL value of $92{,}5\ 5\ \mathrm{gr/cm^3}\ 41{,}73\ \mathrm{gr/cm^3}$

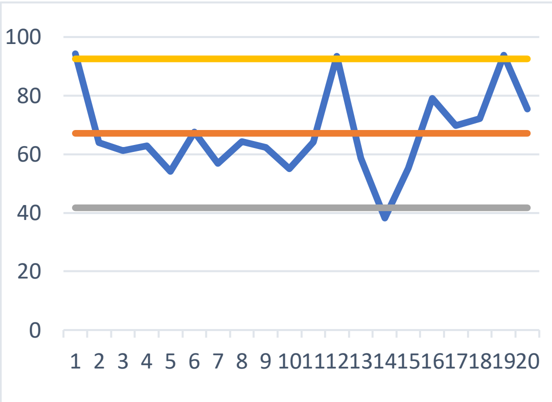


Figure 3 Control map X *Goyang* before revision

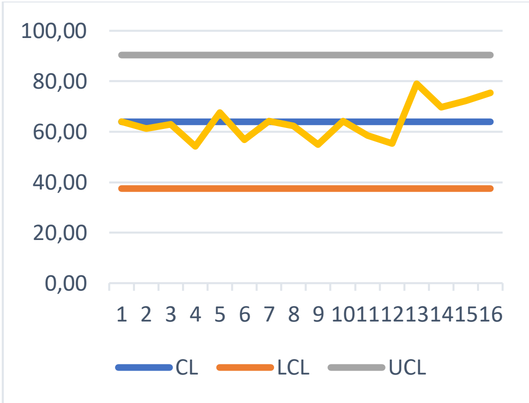


Figure 4 Control map X *Goyang* after revision

After the control map graph is made, it can be seen in Figure 3 that some of the reject proportions exceed the UCL and LCL limits. The proportion of rejects must be eliminated until the proportion can fit all within the UCL and LCL limit range. Figure 4 shows that the proportion of rejected products is already within the UCL and LCL limit ranges by removing four proportions of rejected products that exceed the limit on the previous control map.

Calculate process capability ratio (Cp)

Formula cp = $\frac{USL-LSL}{6\sigma}$ Formula = σ $\frac{\overline{R}}{d2}$ d2 = 3.078

Calculation of process capability in the type of *goyang* defect :

$$\sigma = \frac{R\ Bar}{d2} = \frac{85{,}875}{3{,}078} = 27{,}899$$

$$Cp = \frac{USL-LSL}{6\sigma} = \frac{100-0}{6x27{,}899} = \frac{100}{167{,}394} = 0{,}597\ (\textit{potential capability})$$

$$Cpl = \frac{\overline{X}-LSL}{3x\sigma} = \frac{63{,}93-0}{3x27{,}899} = \frac{63{,}93}{83{,}697} = 0{,}763$$

$$Cpu = \frac{USL-\overline{X}}{3x\sigma} = \frac{100-63{,}93}{3x27{,}899} = \frac{36{,}07}{83{,}697} = 0{,}430$$

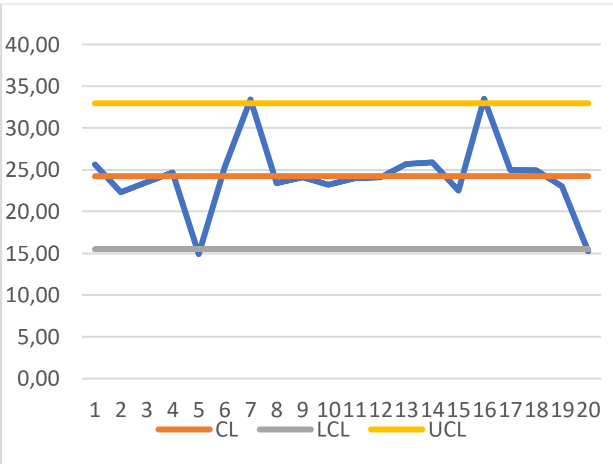
$$Cpk = \min(Cpu; Cpl) = \min(0{,}430; 0{,}763) = 0{,}430\ (\textit{actual capability})$$

The calculation above shows that the process capability is at a value of 0.430 and far below the value of 1. This shows that process capability is low, so intensive improvement and supervision are needed to improve production process capabilities. The next step is to make a variable *reject* diameter control map so that the following data is obtained:

Table 5 Control map X defect of diameter before revision

Sample	$\overline{X}$	*Range*	CL	LCL	UCL	Sampel	$\overline{X}$	*Range*	CL	LCL	UCL
1	25,60	33	24,22	15,48	32,95	12	24,10	25	24,22	15,48	32,95
2	22,30	36	24,22	15,48	32,95	13	25,70	36	24,22	15,48	32,95
3	23,50	21	24,22	15,48	32,95	14	25,90	22	24,22	15,48	32,95
4	24,70	22	24,22	15,48	32,95	15	22,50	38	24,22	15,48	32,95
5	14,90	35	24,22	15,48	32,95	16	33,50	28	24,22	15,48	32,95
6	25,40	32	24,22	15,48	32,95	17	25,00	21	24,22	15,48	32,95
7	33,40	30	24,22	15,48	32,95	18	24,90	34	24,22	15,48	32,95
8	23,40	21	24,22	15,48	32,95	19	23,00	37	24,22	15,48	32,95
9	24,10	32	24,22	15,48	32,95	20	15,20	14	24,22	15,48	32,95
10	23,20	19	24,22	15,48	32,95	Sum	484	567			
11	24,00	31	24,22	15,48	32,95	X Bar	24,22	28,35			

From the control map Table 5 of the reject diameter variable above, it is known that the average value of the measurement results is from 20 observations, with a UCL limit value of and an LCL value of 24,22; 32,95; and 15,48 After the control map graph is made, it can be seen that some proportion of rejects exceed the UCL and LCL limits.



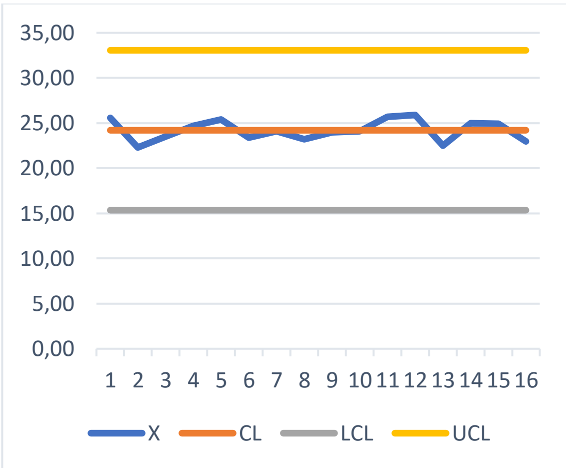


Figure 5 Control map X diameter before revision 566

Figure 5 shows that certain rejects surpass the Upper Control Limit (UCL) and Lower Control Limit (LCL), indicating potential quality issues. The reject proportion must be eliminated until the proportion can fit all within the UCL and LCL limit range. In Figure 6, it can be seen that there is no longer a proportion of defects that are beyond the control limit. This shows that the monitored production process is under statistical control.

Diameter reject process capability calculation:

$$\sigma = \frac{\text{R Bar}}{\text{d2}} = \frac{28{,}75}{3{,}078} = 9{,}34$$

$$Cp = \frac{USL-LSL}{6\sigma} = \frac{40-0}{6 \text{ x } 9{,}34} = \frac{40}{56{,}04} = 0{,}713 \quad \text{(potential capability)}$$

$$Cpl = \frac{\overline{X}-LSL}{3x\sigma} = \frac{24{,}21-0}{3 \text{ x } 9{,}34} = \frac{24{,}21}{28{,}02} = 0{,}864$$

$$Cpu = \frac{USL-\overline{X}}{3x\sigma} = \frac{40-24{,}21}{3 \text{ x } 9{,}34} = \frac{15{,}79}{28{,}02} = 0{,}563$$

$$Cpk = \min(Cpu; Cpl) = \min(0{,}563; 0{,}864) = 0{,}563 \quad \text{(actual capability)}$$

From the above calculations, it is known that the process capability is at a value of 0.563 and is still below the value of 1. It shows that the process capability is low, so improvements need to be made to improve the ability of the production process to be more optimal.

The following are the results of measuring the DPMO value and sigma value (Table 6) :

Table 6 Calculation of sigma value

Sample	(NP)	(N)	DPU	DPO	DPMO	Sigma Value
1	10	10	1,00	0,3333	333333,33	1,9
2	4	10	0,40	0,1333	133333,33	2,6
3	3	10	0,30	0,1000	100000,00	2,8
4	5	10	0,50	0,1667	166666,67	2,5
5	4	10	0,40	0,1333	133333,33	2,6
6	6	10	0,60	0,2000	200000,00	2,3
7	5	10	0,50	0,1667	166666,67	2,5
8	0	10	0,00	0,0000	0,00	0,0
9	5	10	0,50	0,1667	166666,67	2,5
10	3	10	0,30	0,1000	100000,00	2,8
11	8	10	0,80	0,2667	266666,67	2,1
12	5	10	0,50	0,1667	166666,67	2,5
13	4	10	0,40	0,1333	133333,33	2,6
14	4	10	0,40	0,1333	133333,33	2,6
15	5	10	0,50	0,1667	166666,67	2,5
16	7	10	0,70	0,2333	233333,33	2,2
17	2	10	0,20	0,0667	66666,67	3,0
18	5	10	0,50	0,1667	166666,67	2,5
19	7	10	0,70	0,2333	233333,33	2,2
20	6	10	0,60	0,2000	200000,00	2,3
Number of CTQs	**3**					
Total	**98**	**200**	**9,80**	**3,2667**	**3266666,67**	**47,0**
Average	**4,9**	**10**	**0,49**	**0,1633**	**163333,33**	**2,4**

From Table 6, it is known that the disc front brake production process has low process capability. It can be seen from the average DPMO value, which is still relatively high, namely 163333.33, meaning that in one million opportunities, there are still 163333 Pcs, the possibility of the production process producing reject products. In contrast, the average sigma value is at 2.4 sigma, indicating that the production process's capability is still low and is within the average of the Indonesian industry. This is in line with the calculation of process capability on the map of reject variables shake and diameter. It also shows that the process capability is low because it has a value below 1.

The final step at this stage is to perform a cumulative calculation of the rejected data that has been obtained to make it easier to create a Pareto diagram. The results of the calculations that have been carried out are as follows :

Table 7 Calculation of defect and cumulative percentage

Reject Type	Frequency	Cumulative Frequency	Percentage (%)	Cumulative Percentage
Dent	2269	2269	41%	41%
Goyang	1690	3959	31%	72%
Getar	621	4580	11%	83%
Diameter +/-	529	5109	10%	93%
Step	402	5511	7%	100%

Furthermore, a Pareto diagram makes it easier to analyze and determine the priority of rejection that must be resolved first.

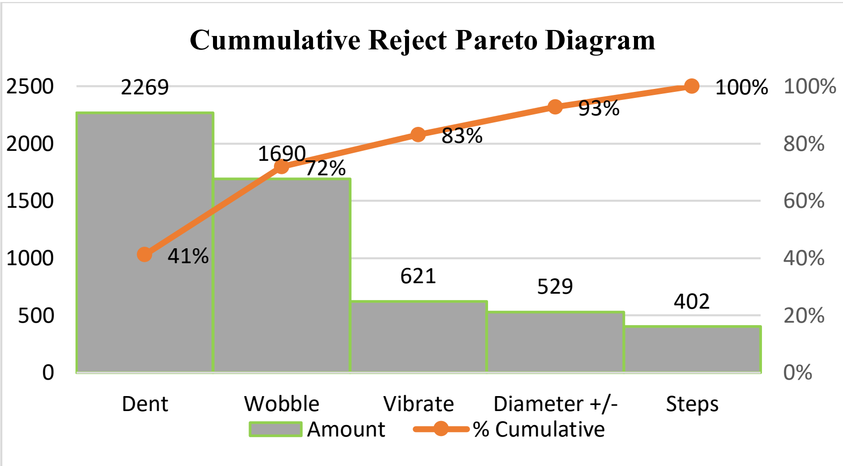


Figure 7 Cumulative Pareto diagram of the number of rejects

Based on Figure 7 of the Pareto diagram above, the priority for improvement is the three largest rejects during 2022: reject dent*, Goyang*, and *Getar*.

3.3 Analysis

The third phase in applying the Six Sigma method is the analysis stage. At this stage, analysis is carried out using the Failure Mode Effect Analysis (FMEA) and Root Cause Analysis (RCA) methods. The FMEA method defines the consequences of failures associated with failures at this stage of the production process and then prioritizes their improvement. While RCA is used in identifying the root cause of failure in the production process (18)

Failure Mode Effect Analysis (FMEA)

At this stage, a corrective action plan is carried out from the types of rejects that often occur. The steps taken to determine priorities in making improvements are to determine the severity, occurrence, and detection (SOD) rating, which is then determined by the value of the risk priority number (Table 8).

Table 6 FMEA disc front brake defects.

No	Kind Rejection	Failure Mode	Effect Failure	S	Causes of failure	O	Control failure	D	RPN
1	*Dent*	There is a gram between the datum and the material when attached to the chuck	*Dent* on Surface machining plane	9	Less clean datum	9	Failure detected during QC inspection	5	405
		The surface of the casting or machining plane is dented	The resulting product does not comply with the desired standard, so the product cannot be distributed	9	Bumped or fallen material	6	Failure detected by the operator during bump/drop event.	6	324
2	Goyang	Inclined material, when clamped by chuck	The material will weigh at a certain point above the specified tolerances	8	The material does not stick to the datum perfectly	6	Failure detected in the balancing machine	4	192
3	Getar	Engine sound In progress Cutting becomes not as always	Results of The plane surface corrugated accidentally disrupts machining	6	Non-standard inserts	7	Failure detected when checking the surface of the machining field one by one	6	252

No	Kind Rejection	Failure Mode	Effect Failure	S	Causes of failure	O	Control failure	D	RPN
		The cutting speed with the spindle rotation is not Balanced	Material can be separated from chuck and Product yield Beyond the standard	8	The machine used is abnormal and lacks safety	6	Failure detected from quantity results and machining surfaces	7	336

Root Cause Analysis (RCA)

At this stage, the preparation of several potential failure factors in causing reject products that often occur on the disc front brake is carried out until the root cause of failure is known(Table 9).

Table 9 Root cause analysis of disc front brake defect

Reject	*Why 1*	*Why 2*	*Why 3*	*Why 4*	*Why 5*	*Why 6*	*Why 7*
Dent	The datum is not clean	There are still grams attached to the material or datum,	Gram is cleaned by hand	Do not spray using an airgun	Gram or coolant splashes can hit the face or eyes	Operators do not use glasses and PPE properly	Operators work not according to SOP
	Material is hit or falls.	The operator is not focused while working	While listening to music through a headset	There was a loud engine sound from several group lines	Operators do not use the earplug PPE that has been provided	There is no SOP regarding the obligation to use earplugs	
Vibrate	Non-standard insert	The eye is cut and inserted with a chip or dent	The insert emits sparks when cutting	Not replaced when the insert's lifetime expires	The inserts in the group line are out of stock	The operator does not apply SCW to the leader	
	The machine used is abnormal and lacks safety	The operator can accelerate the cutting speed without a program key	To speed up cycle time on the machine	Product acquisition is still far from the production target	Operators often leave group lines	Ensure and fill engine oil, which often runs out	The machine lacks maintenance
			The program on the machine cannot be locked	Features of the machine that are not supported	Machines and software use the old type		
		Engine coolant often leaks	The gram in the coolant compartment is full	Gram is not cleaned or drained	Operators shift responsibility to each other	Lack of awareness in machine maintenance	There are no cleaning work instructions, and the person responsible
Wobble	The material does not adhere to the datum perfectly	The material is jammed with gram	Gram sticks to the datum	Do not spray using an airgun	Gram or coolant splashes can hit the face or eyes	Operators do not use glasses and PPE properly	Operators at work do not comply with SOP
		Installation of inclined material	Less emphasis when installing material into the chuck	Arm feels sore	Production targets exceeded		

3.4 Improve

The fourth phase in applying the Six Sigma method is the improvement stage, which provides suggestions for improvements from the data collection results and processing and analysis of each calculation made. Improvement recommendations are made based on the root cause of failure in the production process as follows :

Proposed improvement for dent defect

From RCA, the type of dent defect is known to be the root cause of the rejection. Among others, the operator works not according to the SOP of the PPE glasses used and the absence of SOP regarding the obligation to use earplugs. So the proposed improvements given are as follows :

The proposal to improve the root problem of operators not following the SOP of PPE glasses is to hold training activities to provide operators with the importance of following the SOP implemented by the company. *Training* provided related to SOPs for the use of PPE includes:

1. Operators should not only see PPE as an accessory but not understand its benefits.
2. How and when it is best to use PPE. *Trainers* show how to use different types of PPE in different work area conditions and hazards.
3. What if the PPE used has problems? In order to optimally protect PPE protecting operators, trainers inform them about what they should do if PPE is damaged.
4. How PPE inspection and maintenance is carried out.

Every new or existing operator must receive sufficient training in PPE before carrying out their assigned work duties and responsibilities. PPE training must be routinely carried out with the aim that if there are changes in the workplace, exposure to new hazards, and changes in the type of PPE, operators will be easier to adapt.

Next, *a memo* is made regarding the use of PPE, which must be under the SOP that has been set with a little warning as below (Figure 8) :

MEMO
To : All Machining Departement Operators
The use of personal protective equipment (PPE) when working must be in accordance with established work instructions, including : **Safety Helmet, Safety Glasses, Cotton Mask, Earplugs, Vinyl Gloves, Safety Shoes.**
Remember, your family is waiting for you at home safely!
Prioritize Occupational Safety and Health

Figure 8 PPE usage memo

The proposed improvement of the root cause of the absence of SOPs regarding the *use of earplug* PPE is to create a new SOP by adding *earplugs* as PPE that must be used on the production line. The SOP regarding the use of PPE in question is as follows (Figure 9):

Production Operational Standards (SOP)			
Use of Personal Protective Equipment (PPE) on the Production Line			
Machining Department			
No	**Name**	**Picture**	**Information**
1	Safety Helmet		Helmets are used by operators with the aim of protecting the head from impacts during production.
2	Safety glasses		Operators use safety glasses to protect their eyes from splashes of gram and coolant water during the production process.
3	Cotton Mask		Cotton masks are used by operators with the aim of minimizing occupational diseases due to smoke and steam from machines.
4	Earplug		Operators use earplugs to reduce noise from loud machines, thereby minimizing the occurrence of work-related illnesses
5	Vinyl Gloves		Vinyl gloves are used by operators to protect hands from direct friction with materials and other sharp objects.
6	Safety shoes		Operators use safety shoes with the aim of protecting their feet from impacts or falls from heavy objects and preventing them from slipping (water coolant or oil spilling) during

Figure 9 New SOP with earplugs

With the SOP regarding the use of new PPE standards in carrying out the production process, it is expected that operators can use PPE that has been provided by the company by the SOP and its functions and not use attributes other than the specified PPE that can interfere with the running of the production process.

Proposed improvement for Getar defect

From RCA, defects of the "*Getar"* type, it is known that the root cause of *the reject* includes the operator not applying the SCW SOP, the machine lacking maintenance, and there being no work instructions and jobdesk in draining or cleaning grams on the *coolant* box. So the proposed improvements given are as follows :

The proposal to improve the root cause of the operator not applying the SCW SOP when an abnormality occurs is to hold *training activities* to provide an understanding of the importance of following the SOP implemented by the company. Training materials provided related to SOPs for the use of SCW include:

1. Provide an understanding of the importance of implementation and what impacts are felt when implementing SCW if the production process is abnormal.
2. Provide knowledge to operators about what conditions are included in abnormal events during production.
3. Convey the steps to be taken in implementing SCW and the objectives of these steps.

In addition *to the training* provided to operators, leaders can also make *memos* as below (Figure 10) :

MEMO

To : All Machining Department Operators

Perform a stop-call-wait (SCW) according to the SOP if an abnormality occurs in the machine, material, tools, work environment, and so on related to the production process to avoid bigger problems.

STOP ➡ Stop work
CALL ➡ Call the leader and explain the problem
WAIT ➡ Wait for further instructions from the leader to start production

Prioritize Occupational Safety and Health

Figure 10 Implementation memo of SCW

Remarks: A *Memo* is installed on the door of the machine with the aim that the operator will always see and remember when carrying out the production process.

The proposed improvement of the root cause of the engine's lack of maintenance and the old type of machine from the cause of *vibration rejection* is to make a *maintenance check sheet.* The check sheet in question is as follows (Figure 10) :

Tabel 10 Machine maintenance check sheet recommendations

Check Sheet for Periodic Machine Maintenance on the Produktion Line

No	Point Check	Executor	Month																																																								
			January					February					March					April					May					June					July					August					September					October					November					December				
			1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
1	Engine oil level	Operator																																																										
2	Engine oil change	Operator																																																										
3	Engine oil line	Maintenance																																																										
4	Wind pressure	Operator																																																										
5	Engine temperature	Maintenance																																																										
6	Air Filter	Maintenance																																																										
7	Turret movement	Operator																																																										
8	Responsive chuck	Operator																																																										
9	Completeness of machine buttons	Operator																																																										
10	Machine button function	Operator																																																										
11	Gram filter (coolant box)	Operator																																																										
12	Gram dump conveyor	Operator																																																										
13	Physical condition of the machine	Operator																																																										
14	Machine features or CPU	Maintenance																																																										
	SUPERVISION	Leader 1																																																										
		Leader 2																																																										
		Leader 3																																																										

Information:

The executor or person in charge of carrying out the inspection and maintenance of the machine gives an X sign if it does not perform the inspection and a sign if it performs the inspection. Furthermore, the leader will check the results to ensure the actual treatment is carried out by giving an O mark on the existing check sheet. The leader examines with a period of once a week.

The proposed improvement of the root cause of the absence of a job desk in draining grams in the coolant box from the cause of vibrating reject is to make a schedule and job desk draining in the coolant box, with the following results (Table 11) :

Table 11 Gram cleaning work instructions

Cleaning and Draining Gram Work Instructions																																	
No	Location	Executor	PJ Leader	Month																													
				February					April					June					August					October					December				
				1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
1	Lathe machine 1 right	Operator 1	Leader 1																														
2	Lathe machine 2 right	Operator 2																															
3	Lathe machine 1 left	Operator 3	Leader 2																														
4	Lathe machine 2 left	Operator 4																															
5	Right Milling Machine	Operator 5	Leader 3																														
6	Left Milling Machine	Operator 6																															
	SUPERVISION	Foreman Sector																															

Job desk :

1. The operator is responsible for cleaning and draining grams according to the established schedule.
2. *The leader* is responsible for ensuring that the operator has made the work instructions properly and correctly, as well as for preparing the tools used in cleaning and draining grams.
3. The sector foreman supervises what operators and *leaders* do by giving an O if it is done well and an X if it is not done.
4. The implementation of gram cleaning is only carried out in the morning shift, and the leader fills the check sheet by giving a mark√.

Proposed improvement for "Goyang" defect

From the RCA type of "goyang" defect, it is known that the root cause of *the rejection* is the target set by the leader exceeding the standard limit. So the proposed improvements given are as follows:

The proposed improvement of the root cause of excessive targets from the cause of *reject* shake is to improve the flow in setting production targets carried out by the leader with the following system (Figure 11) :

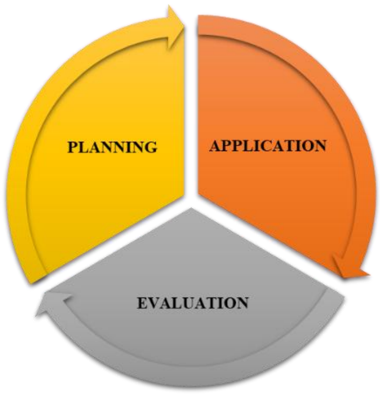


Figure 11 System flow of implementing production target increase

Information:

1. Planning is carried out by leaders who refer to the standard production targets of the company.
2. The application is carried out to know the success rate of the leadership's decisions.
3. Evaluation is carried out as a determinant of whether to continue to use the newly set target or replan the target to be implemented by considering what impacts will be caused.

Furthermore, *a check sheet* is made as a control in implementing changes in production targets from decisions that the leadership has taken (Table 12).

Table 12 Check sheet controls setting new production target increases

Production Target Control Check Sheet																															
PRODUCTION PLAN																															
Date		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Production Target (Pcs)		742	1484	2226	2968	3710			4452	5194	5936	6678	7420			8162	8904	9646	10388	11130			11872	12614	13356	14098	14840			15582	16324
Filled	ACTUAL PRODUCTION GAINS																														
Operator	Shift	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
	Afternoon																														
	Evening																														
	Morning																														
Leader	Amount																														
	Information :																														
	A = Abnormalities in the machine																														
	MT = Materials are late or out of stock																														
	OP = The operator does not come in or leave early																														
	AMOUNT OF REJECT MATERIAL																														
Filled	Reject	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Operator	Dimensi																														
	Dent																														
	Vibrate																														
	Steps																														
	Wobble																														
	Foundry																														
Filled	Amount																														
Foreman	Achievement																														

Information:

1. The operator must fill in the *check sheet* made following the production results obtained, both the total actual production and the number of *rejects*.
2. *The leader* is responsible for summing up the total production and actual rejections and providing reasons if the operator cannot reach the target.
3. *The foremen* are responsible for giving *judgment* by giving an O sign if the operator can reach the new target set and giving an X if the operator cannot reach the given target.

4. Conclusion

The study results found that *reject occurs in the* production process with *an average of 3.45% in 2022 with the types of* reject dent, Goyang, Getar, diameter +/-, and step. The cause of the reject *dent* is that the datum is not clean and the material is bumped or fallen, and the second is the *Goyang reject* with the cause of material failure that does not stick to the datum perfectly. Third is *Getar reject* with non-standard insert failure causes, abnormal machines used, and lack of *safety*.

Several improvement proposals were made to minimize the rejection in the production process, including carrying out *training* programs; the next is to make *memos*. Other proposed improvements are creating new SOPs, creating machine maintenance check sheets, creating gram drain schedules on coolant boxes, implementing new target setting cycles, and making check sheets *as control aids.*

Suggestions that can be given either to the company or subsequent researchers include the company evaluating the system or decisions taken and applied to the production line, implementing improvement proposals that have been recommended from the results of the research conducted, the company is expected to be able to control and supervise the improvements made previously. Further researchers are expected to use the results of this study as consideration and comparison material in the same research topic.

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