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# Optimizing BT-1804 Product Quality with Six Sigma Approach

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## *ABSTRACT*

*PT. Bakrie Autoparts produced BT-1804 products for 12 months, and of the 9537 units produced, there were 3572 product defects with various types of defects. Therefore, Six Sigma with DMAIC is used to minimize defect problems. In stages, define used Critical to Quality (CTQ), where 16 types of potential defects were found in the BT-1804 product. At stage Measure, the Pareto diagram measures the highest frequency of defects and the improvements needed. At stageAnalyze used the Fishbone Diagram, where this method focuses on repairing 1 type of defect in BT-1804, which is the type of machining defect that is the dominant defect. At stageImprove, correcting the root of the problem with FMEA (Failure Mode and Effect Analysis), where it was found that inaccurate machine settings had the highest RPN value of 100. So, suggestions were given by providing knowledge in the form of training related to production mechanisms and providing supervision of operator performance during the machine setting process.*

**Keywords:** *Quality Improvement, Six Sigma, DMAIC; Failure Mode and Effect Analysis*

## Introduction

A company is said to be of quality if the company has a good production system with controlled processes. Quality and productivity are the most frequent discussion topics during the production process. Product quality is the overall characteristics of a product that aim to meet customer needs and expectations in dynamic or continuous conditions. [1] . Product quality is essential for companies to compete and gain a larger market share. [2]. Therefore, companies need a way to produce high-quality products. And continue to improve product quality to remain in line with market demands by implementing a quality control system. [3]. Maintaining or controlling quality, reducing waste, and maintaining process stability make it possible to increase quality and productivity. Products not meeting the required quality standards and classified as defective through inspection are considered faulty products. [4]. Therefore, companies must be able to produce consistent product quality to meet customer needs.

PT. Bakrie Autoparts is a national private company engaged in the car and truck component industry. PT. Bakrie Autoparts always tries to provide the best quality to its customers. PT. Bakrie Autoparts faces complex challenges due to increasing consumer demands for the quality of products made by the company and pressure from similar companies. Therefore, only high-quality products can win the competition and maintain their position in the market under these circumstances because there are still defects in several production processes, PT. Bakrie Autoparts has yet to reach zero defect level because defects are still found in several production processes.

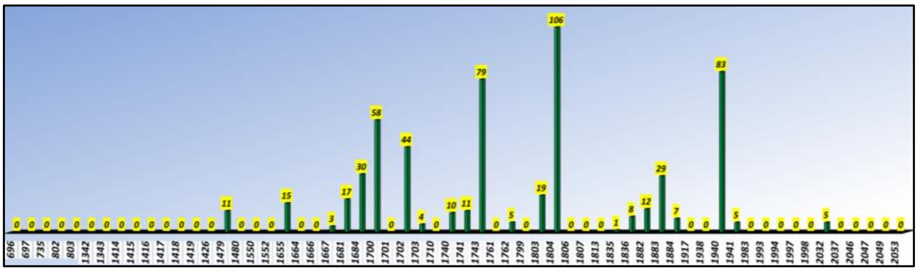


**Figure 1**. Data on The Number of Defects

Figure 1 shows the value of the number of defective products for each part produced over one week. Based on the data, the BT-1804 product has the largest weekly defects, namely 106 faulty products. The Trunion Bracket (Figure 2) is a truck part that is used as a connector and balancer between several parts that will be assembled. So, the trunion bracket is the initial source's central point (home) before assembly for all parts in all positions.

**Figure 2**. Product BT-1804 (Bracket Trunion)

**Table 1.** Total Production and Defect

| Period | Total Production | Total Product *Defect* |
|---|---|---|
| Feb 21 | 387 | 69 |
| Mar 21 | 592 | 142 |
| Apr 21 | 536 | 89 |
| May 21 | 324 | 42 |
| Jun 21 | 568 | 101 |
| Jul 21 | 439 | 100 |
| Aug 21 | 1108 | 1072 |
| Sep 21 | 731 | 570 |
| Oct 21 | 694 | 140 |
| Nov 21 | 1361 | 285 |
| Dec 21 | 1436 | 461 |
| Jan 22 | 1361 | 476 |
| **Total** | **9537** | **3547** |

Table 1 shows that the BT-1804 production results for 12 months show that there were 3547 defective products out of 9537 products produced. Based on the table above, it can be seen that PT. Bakrie Autoparts faced a high defect in the BT-1804 product, which impacted productivity and profitability. Therefore, PT. Bakrie Autoparts aims to minimize the defects in BT-1804 parts, which can result in financial losses or costs and be detrimental in terms of time.

Previous research discovered that applying the Six Sigma methodology in the remanufacturing industry could lead to significant quality improvements and reduced product failure rates, as indicated by the defect rate decreasing from 111 pcs to 24 pcs. It shows the effectiveness of the Six Sigma methodology in reducing defects [5]. A flexible Six Sigma approach and simulation models can effectively improve patient access to clinical assistance in pediatric hospitals, so this research developed a model to simulate and evaluate different strategies to manage and reduce patient no-shows [6]. Implementing Six Sigma in a healthcare company revealed several vital insights and demonstrated that Six Sigma improves processes and promotes a process mindset in organizations [7]. The Six Sigma methodology, especially the DMAIC approach, is important for analyzing and improving the quality of the goods delivery process by identifying and overcoming the main causes of delays to increase efficiency and customer satisfaction [8]. The results of implementing Six Sigma show improved performance in many organizations by reducing costs, increasing productivity, and reducing production cycle times [9]. Implementing the Six Sigma DMAIC methodology reduced the rejection rate of rubber weather threads produced by XYZ Ltd. The initial rejection rate was more than 5%, causing financial losses and affecting customer satisfaction. However, after implementing one Six Sigma project, the rejection rate was reduced, and the process sigma level increased from 3.9 to 4.45 [10]. In several studies, six Sigma is often used to solve quality problems in manufacturing companies [11], [12], [13]. So, there is an attempt to solve the problem above by applying the DMAIC (Define, Measure, Analyze, Improve, and Control) approach. DMAIC is a systematic stage framework for implementing the Six Sigma approach to carry out process improvements and continuous quality improvement in the company [14]. It is hoped that quality evaluation and improvement can be achieved by applying the Six Sigma method, which combines the DMAIC approach. Implementing Six Sigma DMAIC also helps reduce waste so operational costs can be reduced. This, of course, has an impact on increasing company profitability. On the other hand, Six Sigma DMAIC's focus on meeting customer needs increases customer satisfaction and loyalty [15]. In addition, FMEA is used in this research to identify and prioritize possible failures or defects in products to increase consumer satisfaction [16], [17]. FMEA also functions as a systematic analysis tool to identify, analyze, and prioritize potential failure modes and their causes to make targeted improvements in quality improvement efforts according to the Six Sigma approach [18]. In previous research, the FMEA method succeeded in identifying potential causes of product defects along with their level of importance (RPN), so improvements can be proposed by prioritizing factors that have the highest RPN, namely component availability [19]

Therefore, based on previous research studies, researchers recommend the Six Sigma method for solving problems related to improving the quality of BT-1804 at PT. Bakrie Autoparts fulfills consumer desires to guarantee the quality of its products at every stage of the BT-1804 production process.

## Research Methods

### General Stages of Research

The research conducted at the PT. Bakrie Autoparts in Bekasi produced automotive parts. The subjects of this research were Bracket Trunion (BT-1804). Historical Data was collected from February 2021 to January 2022. Before it starts, problems are identified through observation and interviews. This research aims to minimize defects in the BT-1804 product to improve the process. The Six Sigma method was used in this research, whereas DMAIC (Define, Measure, Analyze, Improve, Control) was used in the process. At the define stage, Critical to Quality (CTQ) is used to determine the quality characteristics of BT-1804. Next, the Pareto diagram was chosen at the Measure stage because it can measure priority defects that must be resolved. Apart from that, sigma level measurements were also carried out to determine the current condition of sigma levels. The Analyze stage uses the Fishbone Diagram and 5W+1H to determine the causes of defects. Next, in the Improve stage, FMEA is used to determine the priority causes that need improvement. The control stage ensures the sustainability of each solution.

### Research Flow

In this research, problems with the company were identified. Next, problem formulation, research observation, data processing, and analysis of the results are carried out. The flow of this research can be seen in Figure 3 below:

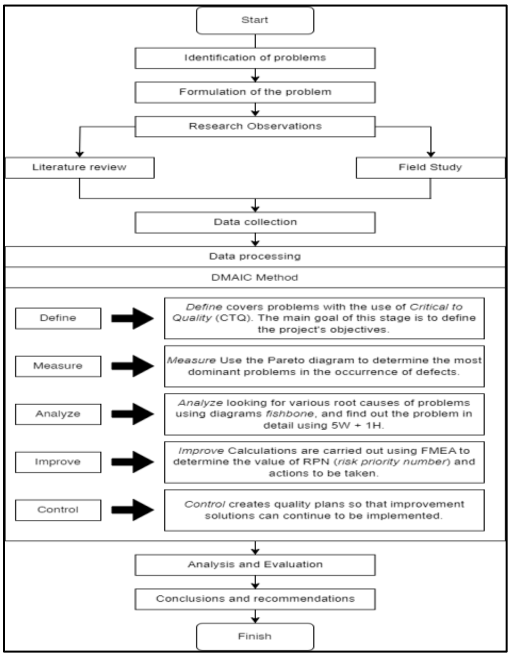


**Figure 3**. Research Flow

## Results and Discussion

In this research, problem-solving was carried out using the DMAIC method, which was applied in several steps. The DMAIC process consists of Defining, Measuring, Analyzing, Improving, and Controlling. [20]. The following are the results of each stage of DMAIC:

### Define

The step Define, Critical to Quality (CTQ) was determined to determine the physical quality characteristics of BT-1804 products and several factors that cause defects. Critical quality (CTQ) is an important step in quality control that defines the factors influencing product quality. [21]. During the BT-1804 production process, several types of physical defects occurred, including human, machine, method, material, and environmental errors, which harmed quality during the BT-1804 production process.

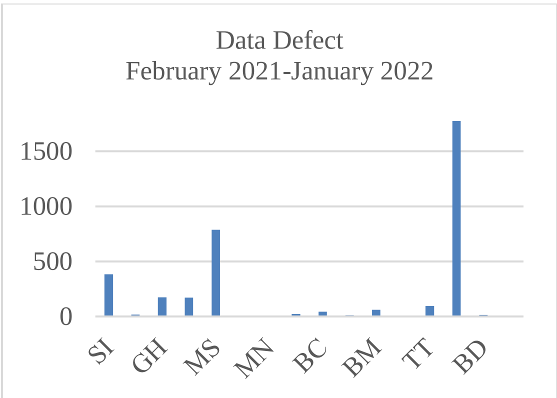


**Figure 4**. Type of Defect

From Figure 4, it can be seen that there are results critical to quality, where it is known that 16 types of potential defects occur in the BT-1804 product, where the type of defect is Sand Inclusion (AND), Scab (SCB), Gas Hole (GH), Shrinkage (SKG), Miss Run (MS), Cross Joint (CJ), Mangan (MN), Outspoken (EXT), Broken Casting (BC), Cracked Mold (MRT), Bad Mould (BM), Swollen (BK), Thick Thin (TT), Machining (MACH), and Bending (BD).

**Measure**

Data processing is carried out at the measure stage using the Pareto Diagram. The Pareto diagram determines a priority category of events so that the most dominant value can be identified by looking at the cumulative value [22]. This research used the Pareto diagram to determine the most common error rates from several factors during the BT-1804 production process. Thus, decisions can be made on how to correct those errors and increase production, which will result in profits for the company and reduce losses.

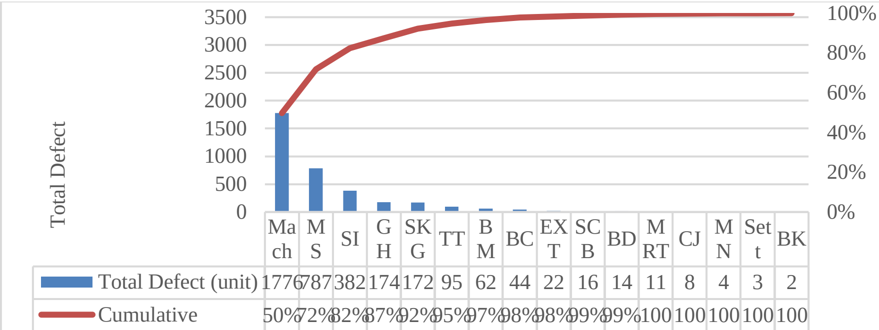


**Figure 5**. Pareto Diagram

Based on the results of Figure 5 above, it can be seen the percentage of causes of defects and the most dominant category of causes of defects, namely Mach (machining), with total defects amounting to 1776 units per year, so it is necessary to identify solutions to dominant defects. Next, a p-chart is used for attribute quality control charts, namely product parts that do not comply with the standards set by the company in the production stage. The following is a diagram control p for BT-1804 products.

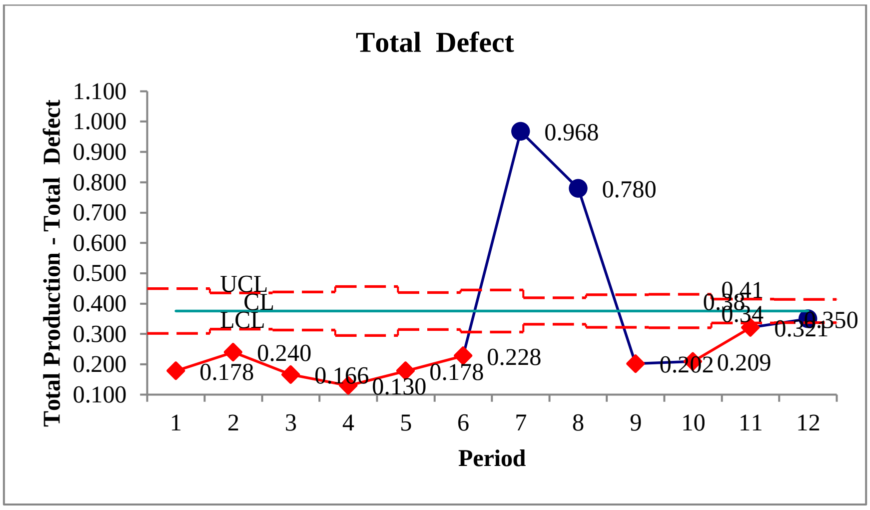


**Figure 6**. p-Chart

In Figure 6, it can be seen that all the values obtained exceed the upper and lower limits. Therefore, researchers found that the defects in BT-1804 products were still outside control limits. Thus, improvements must be made to reduce defects in BT-1804 products so that nothing exceeds the predetermined control limits. Next, the DPMO and Sigma Level values are calculated. DPMO (Defects Per Million Opportunities) is a unit of measurement used to measure the number of defects in a process per one million opportunities for defects to occur [23]. The following is the DPMO formula:

$$DPMO = \frac{Total\ Defect}{Total\ Production\ x\ CTQ}\ X\ 1.000.000 \quad (1)$$

The sigma level measures process capability and represents the level of variation in a process. [24]. The following is the Sigma Level formula:

Level Sigma = NORMSINV ((1.000.000 - DPMO)/1.000.000) +1,5 (2)

So, based on the formula above, the DPMO results and sigma levels from 12 periods can be obtained, namely as follows:

**Table 2**. DPMO and Sigma Level

| Period | Total Production | Total Defect | DPO | DPMO | Sigma Level |
|---|---|---|---|---|---|
| Feb-21 | 387 | 69 | 0,011 | 11143,41085 | 3,79 |
| Mar-21 | 592 | 142 | 0,015 | 14991,55405 | 3,67 |
| Apr-21 | 536 | 89 | 0,010 | 10377,79851 | 3,81 |
| May-21 | 324 | 42 | 0,008 | 8101,851852 | 3,90 |
| Jun-21 | 568 | 101 | 0,011 | 11113,55634 | 3,79 |
| Jul-21 | 439 | 100 | 0,014 | 14236,90205 | 3,69 |
| Aug-21 | 1108 | 1072 | 0,060 | 60469,31408 | 3,05 |
| Sep-21 | 731 | 570 | 0,049 | 48734,61012 | 3,16 |
| Oct-21 | 694 | 140 | 0,013 | 12608,06916 | 3,74 |
| Nov-21 | 1361 | 285 | 0,013 | 13087,80309 | 3,72 |
| Dec-21 | 1436 | 461 | 0,020 | 20064,41504 | 3,55 |
| Jan-22 | 1361 | 476 | 0,022 | 21858,92726 | 3,52 |
| Average | 794,75 | 295,58 | 0,02 | 20565,68 | 3,62 |

Based on the calculation results above, it can be seen that the average sigma value is 3.79. Based on the temporary sigma level results, it can be seen that there is a need for a quality control process that still needs to be improved because it is still below the sigma level standards targeted by the company. Quality control is required to increase the value or sigma level obtained and reduce the possibility of defects recurring.

**Analyze**

Based on the Pareto diagram obtained previously, it can be seen that the main factors are process defects machining the BT-1804 product, which is a fairly large percentage, reaching 49.72%. As a result, dominant errors must be prioritized as the first step in solving the problem. In solving this problem, the researcher carried out an analysis using the following fishbone/cause and effect diagram:

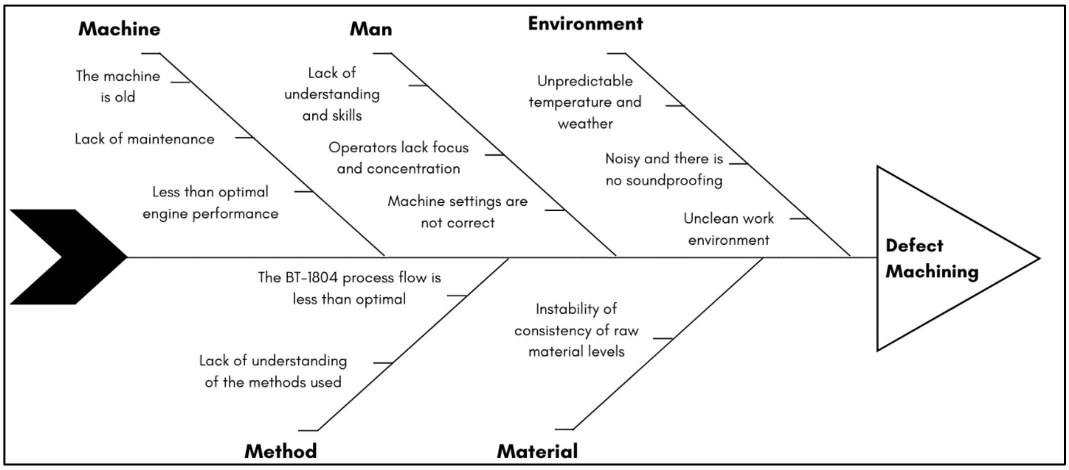


**Figure 7**. Fishbone Diagram

The factors causing the problem that occurs in the image above can be described as follows:

1. Machine
   The machine used can usually cause several errors, including:
   a. In the production process, the old condition of the machine causes the machine to be less productive, which results in the target not being achieved.
   b. The machine's capability in the production process will be reduced due to irregular machine maintenance.
   c. Several obstacles cause the products' results to be less than optimal.
2. Man

Machines usually carry out the product production process, but humans influence product production. Operators determine product quality, which several factors can influence, but humans also play a very active role in the resulting output.

a. Lack of operator understanding of mechanisms in the production process.
b. Operators do not focus and concentrate when working, which results in results that do not align with the company's goals.
c. Inaccurate machine settings can result in product leakage defects.

3. Environment

Where environmental factors will influence production activities, for example:

a. Hot room temperatures will make employees unfocused and produce inappropriate products and unpredictable weather, resulting in products being threatened with corrosion.
b. Noise can cause hearing loss in the long term, which can also affect employee concentration. This will impact employee performance and result in non-compliant products.

4. Method

In the method factor, this usually occurs because supervisors lack or do not supervise during the production process, which reduces employee morale. The following are things that influence these factors, including:

a. Lack of understanding of the methods used; the methods used still have limitations.
b. A production flow that is not optimal without supervision will prevent the work system stated in standard operational procedures (SOP) from being implemented in its entirety. This will impact the product yield and cause defective products to appear.

5. Material

Iron is the main raw material in production, and poor quality may cause unsuitable products. Besides that, raw material BT-1804 is the beginning of the process. Hence, errors often occur, and operators are not careful when starting them. For example, there is instability in the consistency of levels in the raw material used, whether from the sand material used for the product molding or even the metal used for the process. molding.

Apart from using the Fishbone diagram, the 5W+1H method (What, Why, When, Where, Who, How) can also be used to plan defect prevention according to the type of defect in the BT-1804 product. The following is a problem-solving plan table for the product defect due to data processing on the fishbone diagram.

**Table 3**. Problem Management Plan

| **Dominant Factor** | **Dominant Cause** | ***What*** | ***Why*** | ***Where*** | ***When*** | ***Who*** | ***How*** |
|---|---|---|---|---|---|---|---|
| Machine | *Machining* | What improvement plans will be made? | Why is improvement necessary? | Where were the repairs made? | When was the repair carried out? | Who does the repairs? | How to make repairs? |
| | | Recommend to do maintenance *of* machine periodically | To minimize defects in the BT-1804 product | In the BT-1804 production area | March | *Team Project* | Do maintenance of the machine periodically and with greater accuracy by the operator |

**Improve**

This improved phase uses the FMEA method (Failure Mode and Effects Analysis). FMEA (Failure Mode and Effects Analysis) is an analytical method used to identify potential failure modes and evaluate their impact at a higher level. This method helps designers understand the product, choose the right components, and improve the design. [25].

Identify failure modes and their effects by weighting numbers based on the FMEA concept and calculating the RPN value formula based on the equation obtained from the interview results. Calculations using the FMEA method also help determine the most effective corrective actions to resolve the main problem. Several potential factors and failure effects that cause BT-1804 product defects are as follows:

**Table 4**. FMEA *Potential-Effect-Control*

| Product | *Potential Failure Mode* | *Potential Effect of Failure* | *Current Control* |
|---|---|---|---|
| BT-1804 | Machine settings are inaccurate | Production results do not comply with regulations | Carrying out checks to see employee performance |
| | The machine is old | Reduces engine performance | No control |
| | Size exceeds tolerance | The product does not meet the standards | Done again carefully in doing the placement |
| | Lack of Operator understanding | Does not match the company's achievements | Give instructions to each officer |
| | Field conditions are noisy and hot. | Disrupts employee performance concentration. | No control |

FMEA can be used to analyze failure modes in a product and process. To evaluate failures in the process of Failure Mode and Effects Analysis, three indicators are used: Severity (S), Occurrence (O), and Detection (D). The failure mode priority value is determined by multiplying the three indicators, which produces the RPN (Risk Priority Number). This RPN shows the priority level of failure modes in the process. The RPN value indicates a higher order of improvement. The RPN value can be calculated using the following formula:

$$RPN = S \; x \; O \; x \; D \tag{3}$$

Where:
(S) = *Severity* (Effect of Evidence)
(O) = *Occurrence* (Possibility)
(D) = *Detection* (Prevention Level)

**Table 5**. RPN results from *Defect Machining*

| No | *Potential Failure Mode* | RPN | | | |
|---|---|---|---|---|---|
| | | S | O | D | Result |
| 1 | Machine settings are inaccurate | 10 | 8 | 7 | 560 |
| 2 | The machine is old | 2 | 4 | 3 | 24 |
| 3 | Size exceeds tolerance | 7 | 6 | 4 | 168 |
| 4 | Lack of Operator understanding | 6 | 2 | 1 | 12 |
| 5 | Field conditions are noisy and hot | 4 | 4 | 2 | 32 |

Based on the RPN evaluation that has been produced, the causes of failure that have been analyzed using Failure Mode and Effects Analysis (FMEA) will be the basis for improvements to be made. This will help researchers identify problems that occur so that improvements can be made. The following table shows proposals for improving the BT-1804 production process:

**Table 6**. *Recommended Action* FMEA

| No | *Potential Failure Mode* | RPN | *Recommended Action* |
|---|---|---|---|
| 1 | Machine settings are inaccurate | 560 | Providing knowledge in the form of training/seminar |
| 2 | The machine is old | 24 | Upgrade the replacement of old machines with new machines |
| 3 | Size exceeds tolerance | 168 | Provided with the knowledge to reduce inappropriate sizes |
| 4 | Lack of Operator understanding | 12 | Evaluation of employee performance is carried out every period |
| 5 | Field conditions are noisy and hot | 32 | Providing masks and ear protection |

According to the FMEA value weighting, inaccurate machine settings have the highest RPN value and failure rate. Therefore, erroneous machine settings significantly impact the quality of BT-1804 products. Based on the RPN value results, the most dominant factor is inaccurate machine settings. So, the researcher provides suggestions for improvements, namely by providing knowledge in the form of training/seminars related to the mechanisms regarding the production process carried out and supervising the operator's performance when carrying out the process setting towards the machine.

**Table 7**. RPN *Defect Rate*

| ***Potential Failure Mode*** | **RPN Result** | **Percentage** | **Cumulative (%)** |
|---|---|---|---|
| Machine settings are inaccurate | 560 | 70% | 70% |
| The machine is old | 24 | 3% | 73% |
| Size exceeds tolerance | 168 | 21% | 94% |
| Lack of Operator understanding | 12 | 2% | 96% |
| Field conditions are noisy and hot | 32 | 4% | 100% |

Based on the results of the table (Table 8) above, it is clear that several factors cause various types of failure, namely:

1. Machine settings are inaccurate
   This failure has an RPN value of 560 and a failure percentage of 70%. Therefore, inaccurate RPN machine settings greatly affect the quality of the BT-1804 product and must be prioritized when planning repairs. The proposed improvement is to provide knowledge in the form of training/ seminars related to mechanisms regarding the production process carried out and supervise operator performance during the process setting towards the machine.
2. The machine is old
   This failure has an RPN value of 24, with a failure percentage of 3%. Therefore, the level of importance is very influential from the start of production to the end. The proposed improvements are being carried out to replace old machines with new ones.
3. Size exceeds tolerance
   This failure has an RPN value of 168, with a failure percentage of 21%, and the level of importance of the RPN is enough to affect the quality of the BT-1804 product. The proposed improvement is to provide direction/knowledge to all operators to reduce inappropriate sizes.
4. Lack of operator understanding
   This failure has an RPN value of 12, with a failure percentage of 2%. The level of importance is quite influential in production implementation. The proposed improvement is to evaluate employee performance every period.
5. Field conditions are noisy and hot.
   This failure has an RPN value of 32, with a failure percentage of 4%. The level of importance is quite influential on employee performance in the production process. The proposed improvement is to provide personal protective equipment, especially ear protectors, to minimize this failure.

Based on the results of the largest RPN value, it is possible to plan improvements to inaccurate machine settings immediately. With this, the improvement plan proposed by researchers is to provide knowledge in the form of training/seminars related to the mechanisms regarding the production process carried out and supervise operator performance when carrying out the process. Setting towards the machine.

**Figure 8**. BT-1804 Machine Process

**Control**

This control stage ensures the sustainability of each solution. It shows whether improvements produce better or worse results. First, PT. Bakrie Autoparts must ensure that proper work and inspection instructions are in place. If, during the production process, other things are found that interfere with the process, work instructions, and inspections are added for evaluation. Apart from that, new work standards can improve process flows that are not ideal to become optimal by doing some recommended actions in carrying out the BT-1804 production process so that it can minimize the presence of product defects.

## Conclusion

Based on the results of the BT-1804 product defect analysis at PT. Bakrie Autoparts, using the DMAIC method, can conclude that the defects in the BT-1804 were due to several causal factors, including humans, machines, methods, materials, and the environment. Human factors include inaccurate machine settings, lack of understanding and skills from the employee's perspective, and lack of focus on employee concentration. The causative factors for the machine are the old age of the machine and lack of equipment maintenance, which are caused by less-than-optimal engine performance. Factors causing the method are the BT-1804 production process flow, which is less than optimal, and the related lack of understanding of the method used. The causal factor of the material is the instability of the consistency of the substance content of the raw material used. The last environmental factors are room temperature, unpredictable weather, noise that does not have a sound dampener, and a work environment that is not clean. On the BT-1804 product, machining (Mach) has the highest defects with 1776 defects with a percentage of 49.72%, and swollen (BK) has the lowest defects with two defects with a rate of 0.06% during one period, from February 2021 to January 2022, and the highest failure mode is machine settings that are less accurate with values Risk Priority Number of 560 and value Risk Priority Number the lowest is a lack of operator understanding with an RPN value of 12. Proposed recommendations to minimize this defect are to make improvements using the FMEA method, with significant results indicating a failure mode in the process flow that is less than optimal. Machine settings are less accurate by providing knowledge in the form of training/ seminars related to the mechanisms regarding the production process carried out and providing supervision of operator performance during the process setting to the machine so that this will minimize the occurrence of defects resulting from this failure and will improve the quality of the BT-1804 product.

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