Quality improvement on Common Rail Type-1 Product using Six Sigma Method and Data Mining on Forging Line in PT. ABC

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Abstract. PT. ABC is a manufacturing company engaged in the automotive sector that produces components of cars and motorcycles. This study aims to improve quality by using the six sigma method with the DMAIC stage (Determine, Measure, Analyze, Improve and Control) and analyze it using data mining techniques. At the definition stage 7 defects were identified Critical To Quality namely pockmarked, burry, dent, rust, lapping, marking and NG marking. The measure DPMO value is 28,810 and the sigma value is 3,399. In the analysis phase using data mining with the classification method with the decision tree algorithm, the company's decision in decision-making status of Type 1 Common Rail products agreed on the 10 most interesting parameters. Based on FMEA, it is known as the main cause of the Common Rail Type 1, which is the crust on the dies, marking the product that appears and the trajectory of the heating machine to the forging machine that is too far. The improve phase is using Lifetime Card Dies, the marking is concave inward, reducing the running distance of the heating-forging machine and Controlling Check Sheet Product. The DPMO value obtained after improvement is equal to 24095 and the sigma level is 3.476.

Keywords: Six Sigma, Data Mining, Classification, Decision Tree.

1. Introduction
The rapid development of the manufacturing industry gave rise to intense competition among business actors. This gives encouragement for each company to always improve the products produced in terms of quality. PT. ABC is a company engaged in the automotive sector and was founded in 1986 and located in Cikarang, West Bekasi. One problem that is often faced by the manufacturing industry is that the products produced are not always perfect / defective, defective products are parts that cannot be separated from production. Broadly speaking, this company has 3 main lines, namely forging lines, machining and heat treatment. The study focused on the forging line, because it has a high percentage of defects of 11.24% with a defect tolerance of 6.5%. This research is focused on Type 1 Common Rail parts, because the parts have an average percentage of defects each month of 20%. Defective products in this company are categorized into 2, namely hold product and reject product. Hold product is a defective product that can be repaired so that it becomes a good product, reject products are defective products that cannot be repaired or become scrap. This study aims to improve quality by reducing the
number of defects in order to reduce losses such as costs and time incurred from the disability by using the six sigma method through the DMAIC stage and analysis using data mining techniques.

Quality is everything that satisfies customers or according to customer requirements and requirements. To find out whether the quality control performed is good or not, it is done by control chart analysis and to determine the priority of solving the existing problem is done by pareto diagram analysis [1]. Six sigma is a vision of quality improvement towards the target of 3.4 failure per million opportunities (DPMO) for each product transaction (goods / services) and is a new breakthrough in the field of quality management in the form of a control method and quality improvement towards failure rate 0 / zero defect. There are five stages of DMAIC as a characteristic of six sigma, among others, define - measure - analyze - improve - control [2].

Data mining is the process of extracting useful information from data in a large database that has not been known to find meaningful patterns by means of automatic and semi-automatic exploration and analysis. The purpose of data mining techniques is to try to find benefits from a set of data [3].

Classification is the process of finding a model or function that describes and distinguishes classes or concepts of data. The purpose of classification is to find a model from a training set that distinguishes attributes into appropriate categories or classes [4]. Decision tree functions to convert facts into decision trees that represent rules that can be easily understood by natural language [5]. Entropy is the amount of data that is irrelevant to information from a data set. The higher the entropy value means the more symbols appear in the information. Gain is information obtained from changes in entropy in a data set, either through observation or can also be concluded by participating in a data set [6].

Previous research was used as a guideline in conducting research, the following are excerpts of previous research and current research positions can be seen in Table 1.

| No | Topic                                                                 | References |
|----|----------------------------------------------------------------------|------------|
| 1  | Use of Decision Tree for Determining the Period of Student Study Program in Informatics Engineering | [4]        |
| 2  | Application of C4.5 Algorithm to Predict the Acceptance of Prospective New Employees at PT WISE | [5]        |
| 3  | Six Sigma and Data Mining Applications to Improve Quality in Manufacturing Industry | [6]        |
| 4  | Process Performance Analysis and Identification of Dominant Disabilities in Bag Making with Statistical Process Control Methods Implementation of the DMAIC Approach to Improve PVC Pipe Production Process | [7]        |
| 5  | Application of Statistical Process Control (SPC) in Cocoa Beans Processing | [8]        |
| 6  | Six Sigma Method Approach (DMAIC) and Audit Process (CPPP) for Quality Improvement at PT. IGP | [9]        |
| 7  | Use of FMEA and FTA in Isolator Product Quality Control Comparison of Naive Bayes Classification Algorithm, Nearest Neighbour, and Decision Tree in Case Study of Decision Making in Clothing Pattern | [10]       |
| 8  | Model design of quality products by using data mining in R Bakery Company Integration Between Six Sigma, Data Mining-Association Rules, Statistical Process Control (SPC) Methods in Quality Improvement Efforts in Type 1 Common Rail Part at PT. A B C | [11]       |

Position of this research
2. Methods

The research method is using Define-Measure-Analyze-Improve-Control. More detailed stages can be seen in Figure 1.

![Data Processing Flowchart]

**Figure 1.** Data Processing Flowchart

3. Results and Discussion

3.1. Define

Define phase is the process of defining problems, setting goals, and finding opportunities to make improvements. At this stage identification of the process and matters relating to the Type 1 Common Rail part using the SIPOC diagram is carried out. The SIPOC diagram can be seen in the Table 2.

| Supplier          | Input       | Process       | Output          | Customer            |
|-------------------|-------------|---------------|-----------------|---------------------|
| PT. SUMITOMO      | Steel Bar   | Cutting       | Common Rail     | PT. OTICS Indonesia |
|                   |             | Heating       | Type 1          |                     |
|                   |             | Forging       |                 |                     |
|                   |             | Trimming      |                 |                     |
|                   |             | Cooling Control |               |                     |
|                   |             | Grinding      |                 |                     |
|                   |             | Shot Blasting |                 |                     |
|                   |             | Magnetic Particle Inspection | |                     |
|                   |             | Rust Protection |               |                     |

| Supplier          | Input       | Process       | Output          | Customer            |
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|                   |             | Trimming      |                 |                     |
|                   |             | Cooling Control |               |                     |
|                   |             | Grinding      |                 |                     |
|                   |             | Shot Blasting |                 |                     |
|                   |             | Magnetic Particle Inspection | |                     |
|                   |             | Rust Protection |               |                     |
Critical To Quality (CTQ) is a very important attribute because it is directly related to customer needs and satisfaction with a product and service. CTQ is the requirements desired by the customer. Critical to Quality on Common Rail Type 1 can be seen in Table 3:

| No. | Defects  | Details                                           | Occur In Process |
|-----|---------|---------------------------------------------------|------------------|
| 1   | Pockmark| Product surface roughness due to powder / dirt attached to dies | Forging          |
| 2   | Burry   | There are pieces remaining from the trimming process | Trimming         |
| 3   | Dent    | Product surface damage due to impact              | Forging          |
| 4   | Rust    | There is rust on the surface                      | Magnetic Particle Inspection |
| 5   | Lapping No Marking | Natural folds on the surface of the product | Forging |
| 6   | Marking NG | Marking Damaged: There is no / faint print part code | Forging |
| 7   |        | There is a crust and dent on the marking          | Forging          |

3.2 Measure
Based on these observations, the percentage of Type 1 Common Rail part defects was 20.17% with the number of defects as many as 605 units from 3000 units. P control chart is used to find out whether the data used is in the control limit or not by using Minitab Software 17.

![P Chart of Cacat](image)

**Figure 2.** P Control Chart

Based on the graph in Figure 2, it can be seen that all data in control or are within the control limit, with an average value of proportions of 0.2017, lower limit values of 0.0813 and an upper limit value of 0.3220. Furthermore, DPMO and sigma level calculations are performed.

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DPO = \frac{\text{The number of defects found}}{\text{The number of units examined} \times \text{the number of CTQ}} = \frac{605}{3000 \times 7} = 0.02881
\]

\[
DPMO = DPO \times 1.000.000 = 28810
\]

Defect per Million Opportunities (DPMO) in Type 1 Common Rail parts is 28,810 defects in one million opportunities and after conversion, the Common Rail Type 1 sigma part rate is 3.399. Therefore, improvements are needed to increase the sigma level.
3.3 Analyze
This stage aims to determine the potential causes of disability that occur so that the proposed improvements are given on target.

3.4 Classification methods with decision tree algorithms.
This stage aims to determine whether the sample product is in the hold, NG or QC Passed class. The product is categorized as hold if the product is found defective and the defect can be repaired / rework / repair. The product is classified as NG if the product cannot be repaired to become scrap. The product is categorized as QC Passed if the product is not found defective or has passed the inspection. Based on observational data totaling 3000 product samples, it can be seen that as many as 45 units of products were stated NG, 560 units were declared hold and 2395 units were declared QC Passed. The decision tree results for Type 1 Common Rail product observation data can be seen in Figure 3.

![Decision Tree](image)

**Figure 3.** Decision Tree

There are ten parameters that are most influential in the production process of Type 1 Common Rail parts. The most influential parameters are lapping, pockmarking, marking NG, dent, rust, NG pock, NG dent, marking, NG and burry lapping. 11 functions are formed which are formed from the decision tree in Figure 3. The first function is that the product is declared to hold if there are lapping defects. The second function of the product is said to hold if there are no lapping defects but found pockmarked defects, and so on. The example of if then rules table can be seen in Table 4.

| No. | Function   | No. | Function   |
|-----|------------|-----|------------|
| 1   | IF Lapping "YES" | 5   | IF Lapping "NO" |
| 1   | Then Keputusan "HOLD" | 5   | Bopeng "NO" |
| 2   | IF Lapping "NO" | 5   | Marking NG "NO" |
| 2   | Bopeng "YES" | 5   | DENT "NO" |
| 2   | Then Keputusan "HOLD" | 5   | Karat "YES" |
| 3   | IF Lapping "NO" | 5   | Then Keputusan "HOLD" |
| 3   | Bopeng "NO" | 5   | IF Lapping "NO" |
| 3   | Marking NG "YES" | 6   | Bopeng "NO" |
| 3   | Then Keputusan "HOLD" | 6   | Marking NG "NO" |
| 4   | IF Lapping "NO" | 6   | DENT "NO" |
| 4   | Bopeng "NO" | 6   | Karat "NO" |
| 4   | Marking NG "NO" | 6   | Bopeng NG "YES" |
| 4   | DENT "YES" | 6   | Then Keputusan "NG" |
| 4   | Then Keputusan "HOLD" |

Table 4. If Then Rules
There are 10 parameters that have the most influence on the quality of Type 1 Common Rail products, namely lapping, pockmarking, marking NG, dent, rust, NG pocker, NG dent, NG marking, NG, burry. Determination of the types of dominant defects that appear in the production process of Type 1 Common Rail parts is done by making a pareto diagram. Based on the Pareto diagram 80% of the most dominant types of defects are lapping (30.4%), pockmarked (27.6%), marking NG (21.3%) and dent (14.4%).

In analyzing the causes of defects in products used the FMEA method (Failure Mode and Effect Analysis). FMEA considers the value of Risk Priority Number (RPN) which is the result of multiplication between the values of Severity (Sev), Occurrence (Occ), and Detectability (Det). The summary of FMEA table can be seen in Table 5.

### Table 5. Summary of FMEA

| Process | Failure Mode | Potential Effects of Failure | Sev | Potential Cause of Failure | Occ | Current Control of Failure | Det | RPN |
|---------|--------------|------------------------------|-----|---------------------------|-----|---------------------------|-----|-----|
| Cutting | Lapping      | Initial Crack               | 7   | At the end of the material is burry | 4   | Product inspection       | 6   | 168 |
|         |              | Customer has difficulty to claim products | 6   | Product code appears out | 6   | Product inspection       | 5   | 180 |
| Heating | Marking NG   |                              | 7   | Material placement with inappropriate or precise dies | 4   | Making stopper            | 6   | 168 |
|         |              |                              | 7   | Crust on dies             | 7   | Surface Treatment Dies    | 6   | 294 |
| Forging | Lapping      | Initial Crack               | 7   | The trajectory of the heating machine to the forging machine is too far | 5   | Cooling control           | 7   | 175 |
|         |              | Customer has difficulty to claim products | 6   | Product code appears out | 6   | Product inspection       | 5   | 180 |

Based on the calculation of the value of the RPN with FMEA, it is known that 3 causes of potential failure have the highest RPN value so that the proposed improvements are focused on the 3 causes of these potential failures. The highest RPN value is 294 with a potential crust on the dies which gives rise to lapping defects and the second highest RPN value that is equal to 180 with the cause of potential product marking failure that arises causing NG marking defects then the next highest RPN value 175 with other potential failure that is, the trajectory of the heating machine to the forging machine is too far to cause pockmarked defects.

3.5 Improve

Improving phase aims to make efforts to improve the existing problems based on data processing that has been done. Based on the analysis using FMEA, the following are suggested improvements:

### Table 6. Proposed improvements based on FMEA

| Defects  | Potential Causes                          | Proposed Improvement                  | Implementation |
|----------|------------------------------------------|---------------------------------------|----------------|
| Lapping  | There is crust on dies                    | Lifetime Card Dies                    | No             |
|          |                                           | Check Sheet up grade                  | Yes            |
| Marking NG| Product code appears out                  | Concave product code inward           | Yes            |
|          | The distance between heating and forging is too far, causing crust on the product | Reducing the running distance of heating-forging machines. | No             |
3.6 Concave product code inward

The product code is intended as the product code. The initial two letters of the code indicate the material code such as the material arrival schedule and production schedule. Whereas, the numbers indicate the dies code, so that it is known the production time of the dies and can know the age of the dies used. Product code makes it easy to track events from materials and dies used, so that if there is a defect or claim from the customer, the company can easily find out the cause of the defect. In fact, the product code that protrudes out has a higher risk of defects because it is susceptible to impact so it can cause defects in the product code or NG marking. Usually NG marking occurs due to a collision between the product and the collision between the product and the pallet. Therefore, if the product code is made concave inward it can minimize the risk of NG marking or defects in the product code.

![Figure 4. Concave Product Code Inward](image)

3.7 Reducing the running distance of heating-forging machines.

It can be seen that the layout of heating and forging machines is currently at an altitude of 4.4 meters from the production floor and has a sloping length of 5 m. Machine layout heating and current forging and proposals can be seen in Figure 5.

![Figure 5. Engine Heating and Forging Layout](image)

Proposed repairs with a height of 1.9 meters and a sloping side of 2 meters are designed to cut the long distance. The shorter the distance of the track can reduce the temperature of the material, which means a decrease in electricity consumption, can also reduce the crust arising from a decrease in temperature.

3.8 Control

The results of the implementation of the proposed improvements given to determine the effectiveness of the proposed improvements and to find out whether or not the effect of the proposed improvements is significant.

Defect per Million Opportunities (DPMO) in Type 1 Common Rail parts amounted to 24,095 defects in one million opportunities and after conversion, the Common Rail Type 1 sigma part level was 3.476. This shows that the sigma level of the Type 1 Common Rail part production process after implementation of improvement increases by 0.077 sigma.

4. Conclusion

Based on data processing and analysis of the results that have been done, it can be concluded from this study that:
1. In the Type 1 Common Rail part production process, the DPMO value before implementation is 28,810 defects in one million opportunities and the sigma value is 3.399.

2. In the analysis phase using data mining with the decision tree algorithm classification method, the company’s decision in decision making on the status of Common Rail Type 1 products is based on the 10 most influential parameters, namely lapping, pockmarking, marking NG, dent, rust, pocked NG, NG dent, NG, burry, marking and lapping.

3. Proposed improvements given based on the FMEA table are using markings made concave inward and reducing the heating-forging machine track distance.

4. The DPMO value after the implementation of the proposed improvement is 24095 and the sigma value is 3.476 so that it experiences a sigma increase of 0.077 sigma.

5. References

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