Reducing defects in Mile line Of Rolling Plate Departement Using Six Sigma Method

Erni Krisnaningsih¹*, Andreas Tri Panudju², and Ikhwanul Pratama¹

¹Industrial Engineering Study Program, Engineering Faculty, Universitas Banten Jaya, Serang, Indonesia
²Industrial Engineering Study Program, Engineering Faculty, Universitas Bina Bangsa

Abstract
PT. Krakatau Posco is steel company that produces steel and distributes its products both for national and international market. PT. Krakatau Posco produces slabs and plates steel. In meeting the requirements of the markets, the high-quality products are a necessary, thus the company should improve their product quality by reducing defects. The purpose of this study is to identify product defects and to determine the factors that cause during the production process, to propose corrective actions to reduce the number of defects. This research was conducted at Mill Line on Plate Rolling Department PT. Krakatau Posco. The research uses the Six Sigma method. Following the Six Sigma method, the result of DPMO is 568 with δ value is 4.87 which is still under the world target which is 6δ (3.4 DPMO). Proposals steps for improving the quality of plate products are doing routine maintenance and repairing of the machine, checking engine calibration conditions, improving the quality of slab material, heating slab time > 180 minutes, setting parameters (thickness, width, and length) as specified, and checking the straightness of the product plate during the rolling process (camber correction).

1. Introduction
Quality has become a very important part in the production process. A strategy that can guarantee quality is a strategy that is able to maintain the stability of the process, so that the process can be controlled with the aim of being able to minimize defective products. Quality control is an engineering and management activity by which these quality characteristics can be measured, compare them with specifications or requirements, and take appropriate action if there is a difference between the actual appearance and the standard. So companies are required to be able to produce consistent product quality in order to meet customer needs. The company's policy steps in efforts to improve and improve product quality is a step that must be realized. As a first step in the reform, it is necessary to carry out research on the production process to determine deviations that occur due to nonconformity of product defects from specifications set by the company. The improvement and improvement is very necessary for productive business activities to be managed, so that later it can increase overall company productivity. The components involved therein include: human resources, materials, machinery / equipment, facilities and work methods. Increased productivity is determined by increasing the effectiveness and efficiency of the company. To increase productivity and efficiency is done by improving work processes so that waste and inefficiency can be reduced and the quality of the products produced can be further improved.

2. Method
Based on these elements, Goetsch and Davis (1994) make a definition of quality that is broader in scope. The definition is "Quality is a dynamic condition associated with products, services, people, processes, and the environment that meets or exceeds expectations".
According to Pande, Peter S (2002), another definition of Six Sigma is an almost perfect goal in meeting customer requirements. Basically, the definition is also accurate because the term "Six Sigma" itself refers to operating performance targets that are measured statistically with only 3.4 defects for every million activities or opportunities. Only a handful of companies or can claim to have achieved this goal. Six sigma benefits include:

1. Cost reduction
2. Increased productivity
3. Market share growth
4. Customer retention
5. Reduction of cycle time
6. Reduction of defects
7. Product / service development

Here are some terms that are commonly used and will facilitate the understanding of Six Sigma, among others: (Gaspersz, 2002: 6)

1. Critical To Quality (CTQ), these are very important attributes to consider because they are directly related to customer needs and satisfaction. CTQ is an element of a product, process, or practice that has a direct impact on customer satisfaction.
2. Defect, is a failure to provide what the customer wants.
3. Defect per unit (DPU), is a measure of the possibility of defects or failures per unit, calculated by the equation.
4. Defect per opportunity (DPO), is a measure of failure calculated in a six sigma quality improvement program that shows the number of defects or failures per chance. DPO is the development of the DPU concept coupled with the variable opportunity (possibility). Calculated by equation.
5. Defect per million opportunities (DPMO) is a failure in the six sigma quality improvement program, which shows failure per million opportunities. DPMO can be calculated using the formula: DPMO = DPO x 1,000,000 Understanding of DPMO is very important in measuring the success of six sigma quality improvement program applications.
6. Process capability is the ability of the process to produce or deliver output in accordance with customer expectations and needs.
7. Variation, is what customers see and feel in the transaction process between suppliers and customers. The smaller the variation the more preferred because it shows consistency in quality.
8. Stable operation, guarantees the consistency of processes that can be estimated and controlled to improve what customers see and feel and increase customer expectations and needs.
9. Design for six sigma, is a design to meet customer needs and process capabilities. DFSS is a systematic methodology that uses training and measurement equipment to enable suppliers to design products and processes that meet customer expectations and needs and can be produced or operated at six sigma quality levels.

Table 1. Simplified Sigma Level

| Yield (Probability Un-Defects) | DPMO (Defect Per Million Opportunity) | Sigma Level | Remarks |
|-------------------------------|----------------------------------------|-------------|---------|
| 31%                           | 691.462                                | 1-sigma     | Very uncompetitive |
| 69.20%                        | 308.538                                | 2-sigma     | Indonesian Industry |
| 93.32%                        | 66.807                                 | 3-sigma     | Average |
| 99.379%                      | 6.210                                  | 4-sigma     | USA Industry Average |
| 99.977%                      | 233                                    | 5-sigma     |                     |
| 99.9997%                     | 3.4                                    | 6-sigma     | World Class Industry |

The step of the data analysis method is data processing carried out using Six Sigma with the DMAIC method (Define, Measure, Analyze, Improve, Control). The stages of the DMAIC method used in data processing are the Define stage and the Measure stage which are explained as follows:

a. Define Stage. At this stage the steps are as follows:
   1) Statement on the objectives of the six sigma project selection
   2) Determination of the six sigma project selection criteria
   3) Definition of Critical to Quality (CTQ) quality characteristics

b. Measure Stage. At this stage the steps are as follows:
1) Identifying the company's performance standards through the calculation of sigma level (sigma level) and the level of Defect Per Million Opportunity (DPMO).

2) Selection of the dominant CTQ characteristics using Pareto diagrams to be prioritized in problem solving.

   c. Analyze
   
   1) This stage analyzes the causes of defects in the product by first identifying potential causal factors using Cause & Effect Diagrams.
   
   2) Using the Failure Mode and Effect Analysis (FMEA) to analyze the risk of failure in processes and products that affect / have a direct impact on the level of quality of steel sheet products (plate) by determining the value of Risk Priority Number (RPN).
   
   d. Improve. This stage is planned corrective actions to overcome or prevent defects in the product. Corrective action recommendations based on the results of the analysis obtained from the analize phase in the form of potential factors causing defective products.
   
   e. Control is the final analysis phase which emphasizes the dissemination of corrective actions to be taken. Control is carried out after the recommendations for corrective actions are implemented and provide significant improvements to the process and the product.

3. Result and Discussion

Total production and total defect production of PT. Krakatau Posco can be seen in Table 2 as follows:

| No | Periode  | Production (tons) |
|----|----------|-------------------|
| 1  | January  | 72.997            |
| 2  | February | 73.386            |
| 3  | March    | 96.163            |
| 4  | April    | 97.122            |
| 5  | May      | 103.333           |
| 6  | June     | 100.713           |
| 7  | July     | 103.423           |
| 8  | August   | 100.920           |
| 9  | September| 91.724            |
| 10 | October  | 97.247            |
| 11 | November | 95.690            |
| 12 | December | 103.423           |

| No | Defect Code | Defect Name        | Defect Classification | Information |
|----|-------------|--------------------|-----------------------|-------------|
| 1  | 51          | Not Good Width     | NGW                   | If wide total of mother plate is less than plate product design. |
| 2  | 52          | Not Good Length    | NGL                   | If length total of mother plate is less than plate product design. |
| 3  | 53          | Thickness Whole    | NGTW                  | If the amount of thickness in one mother plate is less or more than the standard thickness that is allowed (overall). |
| 4  | 54          | Thickness Partioal | NGTP                  | If the amount of thickness in a part of the mother plate is less or more than the standard thickness that is allowed (in part). |
| 5  | 55          | Not Good Length and Width | NGLW | If the length & width of the mother plate is less than the design of the plate product. |
The Six Sigma approach used in a quality improvement project consists of 5 phases called DMAIC (Define, Measure, Analyze, Improve and Control) which are stages of a very systematic process and refer to facts that occur to make continuous improvements. DMAIC is described as a closed loop that continues to eliminate unproductive stages. In each stage carried out is applied by Six Sigma tools.

3.1. Determination of ctq (critical to quality)
Determination of Critical to Quality (CTQ) is done by processing the customer's voice (voice of customer) into a quality language that can present the main product character desired by the customer. In this study the type of defect data that is grouped can be seen in Table 5 as follows:

3.1.1. Measure
Measure is the second operational step in the Six Sigma quality improvement program. This stage is one of Six Sigma's differentiators with other quality control methods. Measurements were made to assess the conditions of existing processes.

3.1.2. Measurement of DPMO (Defect Per Million Opportunities) and Sigma Value (ơ)
Calculation of the product sigma value is carried out using standard sigma calculation formulas, and also by using the available sigma value tables. The sigma calculation method is used specifically for discrete data. Before calculating the sigma value, it is important to know the opportunity that affects the sigma value. Opportunity is an opportunity that allows defects. The more opportunities that are used, the greater the value of the paradigm. This has the sigma value obtained is not the sigma value that actually occurs in the process. For that, the number of opportunities used must really be able to represent the conditions of defects that occur. DPMO values for the January 2017 period are obtained using the following equation (Example calculation):

\[ DPMO = \frac{Total\ Defect}{Total\ Quantity\ of\ Production \times Opportunities} \times 10^6 = \frac{93.24}{72.997 \times 5} \times 10^6 = 255 \]

Sigma value (ơ) is a measure of company performance that illustrates the ability to produce defect-free products. The sigma value (ơ) for the January 2017 period is obtained using the following equation (Example calculation):

\[ \text{Nilai} \ \sigma = NORMSINV \left( \frac{10^6 - DPMO}{10^6} \right) + 1.5 = NORMSINV \left( \frac{10^6 - 255}{10^6} \right) + 1.5 = 4.97 \]

| Table 4. DPMO values and sigma (ơ) steel sheet products |
|--------------------------------|-----------|-------|-------|--------|--------|
| Period      | Production (tons) | Defects (tons) | Total CTQ | DPMO   | Sigma (ơ) |
|-------------|------------------|---------------|-----------|--------|-----------|
| January     | 72.997           | 93.24         | 5         | 255    | 4.97      |
| February    | 73.386           | 107.42        | 5         | 293    | 4.94      |
| March       | 96.163           | 97.62         | 5         | 203    | 5.04      |
| April       | 97.122           | 268.11        | 5         | 552    | 4.76      |
| May         | 103.333          | 90.88         | 5         | 176    | 5.07      |
| June        | 100.713          | 51.41         | 5         | 102    | 5.21      |
| July        | 103.423          | 100.91        | 5         | 195    | 5.05      |
| August      | 100.920          | 90.34         | 5         | 179    | 4.41      |
| September   | 91.724           | 143.32        | 5         | 313    | 4.92      |
| October     | 97.247           | 207.55        | 5         | 427    | 4.83      |
| November    | 95.690           | 100.91        | 5         | 211    | 4.36      |
| December    | 103.423          | 207.55        | 5         | 401    | 4.85      |
| Total       | 1.136.141        | 1559.26       | 5         | 276    | 4.98      |

The recapitulation of the calculation results can be seen in Table 6 above. These results are far from the standard adopted by Six Sigma, namely DPMO of 3.4 with a sigma value of ơ6 and the percentage of non-defective products of 99.9996%. However, the DPMO value of 276 and the sigma
(σ) value of the process of 4.98 σ are good enough when compared to the industry average in Indonesia.

3.2. Determination of Dominant Potential CTQ

There are 5 potential CTQs that can cause readability to the product. From the five potential CTQs, there are several types of CTQ that are dominant. The dominant CTQ criteria is that CTQ most often appears on products with the largest percentage of disabilities against all CTQ numbers and occurs repeatedly. The percentage of defects for the type of defect Not Good Width (NGW) is (Example calculation):

\[
\% \text{ defect} = \frac{\text{Total of Defect per CTQ}}{\text{Total Quantity Of Defect}} \times 100\% = \frac{324.20}{1559.26} \times 100\% = 20.79\%
\]

| Table 5. Recapitulation of Potential CTQ of Steel Plate Products |
|---------------------------------------------------------------|
| Period           | Critical to Quality (CTQ) | Total (tons) |
|                 | NGW | NGL | NGTW | NGTP | NGLW |                  |
| January         | 27.15 | 35 | 10.75 | 5.11 | 15.23 | 93.24          |
| February        | 15.1 | 80.23 | 2.07 | -    | 10.02 | 107.42         |
| March           | 30.44 | 35.12 | 5.23 | 6.32 | 20.51 | 97.62          |
| April           | 42.2 | 104.81 | 15.52 | 25.35 | 80.23 | 268.11         |
| May             | 15.82 | 25.12 | 25.32 | 15.2 | 9.42 | 90.88          |
| June            | 25 | 23.03 | -    | -    | 3.38 | 51.41          |
| July            | 21.02 | 52.32 | -    | 11.52 | 16.05 | 100.91         |
| August          | 15 | 40.54 | 10.2 | 4    | 20.6 | 90.34          |
| September       | 42.12 | 62.03 | -    | -    | 39.17 | 143.32         |
| October         | 42.51 | 120.35 | -    | -    | 44.69 | 207.55         |
| November        | 15.25 | 67.48 | -    | 8.12 | 10.06 | 100.91         |
| December        | 32.59 | 126.32 | -    | -    | 48.64 | 207.55         |
| **Total Defects (ton)** | **324.20** | **772.35** | **69.09** | **75.62** | **318** | **1559.26** |
| **Defects (%)** | **20.79** | **49.53** | **4.43** | **4.85** | **20.39** | **100.00** |

In Table 5 the recapitulation of potential CTQ steel sheet products is a table that shows the results of calculations in finding the percentage of 5 types of defects. After obtaining a percentage value for each type of CTQ, then CTQ is sorted starting from the largest percentage and calculated cumulatively as in Table 6.

| Table 6. Cumulative percentage of potential CTQ of steel plate products |
|---------------------------------------------------------------|
| No | Critical to Quality (CTQ) | Total Defects (tons) | Defects (%) | Cumulative (%) |
|----|---------------------------|----------------------|--------------|----------------|
| 1  | Not Good Length (NGL)     | 772.35               | 49.53        | 49.53          |
| 2  | Not Good Width (NGL)      | 324.20               | 20.79        | 70.32          |
| 3  | Not Good Length and Width (NGLW) | 318 | 20.39 | 90.72          |
| 4  | Not Good Thickness Partial (NGTP) | 75.62 | 4.85 | 95.57          |
| 5  | Not Good Thickness Whole (NGTW) | 69.09 | 4.43 | 100.00         |
| **Total** | **1559.26** | **100.00** |

In Table 6 the cumulative CTQ percentage of potential steel sheet products is a table that shows the percentage value of each type of disability that exists and ranks it from the largest defect rate to the smallest defect rate. To find out the dominant type of disability Pareto diagram is used as shown in the following Figure 2:
From figure 2 the pareto diagram of the types of steel sheet product defects (plate) above can be seen the type of dimensional defects in steel sheet products (plates) with the largest percentage, namely for the types of defects Not Good Length (NGL) and Not Good Width (NGW). The cumulative percentage for both types of disabilities reaches 70.32%. This value is in accordance with the Pareto 80/20 principle, where 80% of defective products are caused by 20% of defects. So as to reduce the number of defective products to 80% or more, it is enough to control both types of defects. Because if controlling all types of disabilities that occur will be inefficient because it will take time, costs and enormous energy.

**Analyze**

At this stage an analysis of the factors that cause dominant defects in steel sheet products (plate). Analysis in the current research uses Cause and Effect Diagrams.

**Cause & Effect Diagram Analysis**

Cause-Effect Diagrams are known as fishbone diagrams. This diagram is useful for analyzing and determining factors that have a significant influence in determining product quality characteristics based on rational categories. Besides that it is also useful to find the real cause of a problem.

**Cause and Effect Diagram Not Good Length (NGL)**

From the Pareto Diagram, it can be seen that the largest number of defects occurred in Not Good Length (NGL), namely 772.35 tons. Thus an analysis of the causes of errors on these types of errors using Cause and Effect Diagrams, as shown in Figure 3 & 4 below:

**Figure 3. Cause and effect Diagram Not Good Length (NGL)**

**Figure 4. Cause and effect Diagram Not Good Width (NGW)**

**Cause and Effect Diagram Not Good Width (NGW)**

From the Pareto Diagram it can be seen that the second largest number of defects occurred in the Defect Not Good Width (NGW) which is 324.20 tons. Thus an analysis of the causes of errors in these types of defects using Cause and Effect Diagrams, as shown in Figure 4

**Similarity Analysis of the Causes of Product Defects**

From the description of Case and Effect Diagrams, SIPOC (Suppliers-Input-Process-Outputs-Customer) Diagrams. Can be seen the source of the cause of the dominant type of defect in steel sheet
products (plate). Method, human, and environmental factors are common causes for all types of disabilities. While the engine and material factors are special causes of disability, where each type of disability is usually caused by a different machine and material error. However, there are several common sources of causes of defects between the two types of dominant defects and other types of disability, especially those caused by machine and material factors which can be seen in Table 7 below:

| Type of Defects | Slab Scarfing | Control Gap When Reducing | Measuring Machine |
|----------------|--------------|---------------------------|-------------------|
| Not Good Length (NGL) | Slab weight less | Poor compensation, the gap is too thick | Inaccurate length measurement |
| Not Good Width (NGW) | Uneven surface / slab surface | Less compensation, less width | Inaccurate width measurement |

By controlling all the factors causing the occurrence of the two types of dominant defects, indirectly there is a possibility of reducing the occurrence of other types of defects due to the similarity of the causative factors.

Improve

In this step a six sigma quality improvement action plan is implemented, through improvements to the sources that cause defective products. Improvements are made to all sources that have the potential to create defective products based on the analysis of cause and effect diagrams.

The proposed improvement offer for the type of defect that most influences (highest frequency), namely the defect Not Good Length (NGL) and Not Good Width (NGW) types are as follows:

1. Human (HR). Provide training to operators in the Rolling unit. The training / training given to operators is about the work system and the actions that must be taken if an interruption occurs that cannot be overcome manually. Creating Team Cohesiveness. Method

   a. Provide guidance on setting the compensation parameters thickness, width, and length adjusted to the specified size. Provide briefing about the rolling technique and how to correct cambers, skews, etc. before damage / defects occur during the rolling process, so that if there is a broken plate / defect then it can be quickly overcome.

2. Machine

   Checking and preparing before rolling. Checking the elements of the machine, especially on the engine needs to be done as thoroughly as possible. Perform maintenance on the machine. Care for machine elements from minor damage before resulting in a major problem needs to be considered.

3. Material or Material. Slab quality. During the production process also must be observed / monitored. The quality of the slab must be checked to comply with the standard.

Control

The final stage of analysis of Six Sigma is the control stage (control phase). Therefore we need a standardization, documentation and dissemination of actions so that failures that have occurred do not happen again. Actions that need to be done are:

1. Make a standard for all corrective actions in the process in the form of Standard Procedure (SOP) that is attached to the relevant department or work station.
2. Perform routine DPMO and sigma level calculations every period to determine the ability of the process to produce flawless products per million opportunities.
3. Perform routine maintenance and repair of the machine.
4. Check the quality or quality of materials / raw materials and slab information.
5. Check the engine calibration or FM Zeroing condition.
6. Check the heating slab time required at least 180 min.
7. Operators must always focus when operating or rolling, not talking, let alone playing mobile phones at work.
8. Check the parameter settings for dimensions of thickness, width, and length.
9. Check plate alignment during rolling (camber correction).
4. Conclusion

From the overall research conducted, the conclusions obtained can reach the stated research objectives. The conclusions are as follows:

Defect Per Million Opportunity (DPMO) value is 276 and $\sigma$ 4.98 which means it is far from the world class industry level that reaches 6 sigma with a DPMO value of 3.4.

There are 5 types of Critical To Quality (CTQ) defect criteria for steel sheet products, namely: Not Good Width (NGW), Not Good Length (NGL), Not Good Thickness Whole (NGTW), Not Good Thickness Partial (NGTP), and Not Good Length and Width (NGLW). And the most dominant types of defects that appear are Not Good Length (NGL) and Not Good Width (NGW).

Factors that cause the dominant defects that have been identified through cause and effect diagrams, the factors that cause failures in the process that result in the emergence of defective products are work methods that are not mastered, raw materials are received not according to the standard (weight slab scarfing), the machine has skew conditions or the alignment of the machine is not good, failure due to humans / operators occurs due to negligence at work, lack of accuracy and concentration of work.

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