# Quality Improvement Proposal of Spun Pile Using Six Sigma Method at PT. Adhi Persada Beton

IntanArizka[1,*] Dorina Hetharia[1] Anik Nur Habyba[1]

[1] *Department of Industrial Engineering UniversitasTrisakti Jakarta, Indonesia*
[*]*Corresponding author. Email: intan063001700058@std.trisakti.ac.id*

**ABSTRACT**

PT. Adhi Persada Beton is a subsidiary of PT. Adhi Karya (persero) tbk, which produces precast concrete, including spun pile. There was a problem in spun pile production; the average percentage of spun pile defects was 0.71%, exceeding the company standard, which was 0.5%. Therefore, this research was conducted to analyze the defect and provide improvement proposals to reduce the defective products. Five dominant defects that occurred were fin, chipped, sticky skin, curved, and broken. Based on the Spun Pile production process analysis, the DPMO of 617, and sigma level value of 4.73. Based on these criteria, the improvement proposal will be evaluated. The apriori algorithm indicated two defects have a strong combination relationship; they are Curved and Sticky Skin. Another defect prioritized to solve is Fin, the second-highest RPN from FMEA analysis. The use of rust remover can make the improvement proposal given to overcome fin defects. The use of mold cleaning forms is to overcome sticky skin and curved caused by unhardened concrete using a Thermocouple on steaming tubs. This research can only be carried out until the improvement stage because the proposed improvements cannot be implemented due to the lockdown situation at the factory.

***Keywords:*** *DMAIC, apriori algorithm, FMEA, spun pile.*

## 1. INTRODUCTION

PT. Adhi Persada Beton is industry that produces precast concrete. Many products are produced, one of them is Spun Pile that had many defect issue. Spun Pile is a round hollow stake product produced by the centrifugal spinning method. It is usually used for bridges and buildings. Based on historical data in 2020, during the production of Spun Pile, several defective products occurred. Defects that occurred cause the product does not meet the quality standards that the company has set, so it requires quality improvement [1].

Based on historical data in Table 1, the average defect that occurred from January to December 2020 amounted to 0.71% exceeding the standard of PT. Adhi Persada Beton is 0.5%. The type of defect that occurs in Spun Pile products is sticky skin, chipped, porous, crack, fin, broken, dented joint plate, slanted joint plate, and curvy. Defective products cause loss of cost and time incurred by the company to repair or reproduce. DMAIC is a methodology of the six sigma approach that has been proven to improve product quality and reduce cost of poor quality (COPQ) [2]. The method used in this research is the DMAIC approach.

**Table 1**.Historycal data of spun pile in Jan-Dec 2021

| No | Month | Total Production | Defective /Month in pcs | Defective Percentage |
|---|---|---|---|---|
| 1 | January | 285 | 5 | 1.75% |
| 2 | February | 161 | 1 | 0.62% |
| 3 | March | 505 | 2 | 0.40% |
| 4 | April | 371 | 2 | 0.54% |
| 5 | May | 914 | 3 | 0.33% |
| 6 | June | 1124 | 6 | 0.53% |
| 7 | July | 1177 | 6 | 0.51% |
| 8 | August | 1604 | 10 | 0.62% |
| 9 | September | 274 | 5 | 1.82% |
| 10 | October | 1510 | 6 | 0.40% |
| 11 | November | 1197 | 7 | 0.58% |
| 12 | December | 1684 | 7 | 0.42% |
| **AVERAGE** | | **901** | **5** | **0.71%** |

The stages of the DMAIC approach are Define, Measure, Analyze, Improve, and Control[3]. DMAIC process has been proven to improve product quality. Several previous studies have been conducted and have proven the benefits of this methodology in increasing the value of sigma in various companies. Various types of manufactures both in Indonesia and abroad still use DMAIC a lot. Some studies prove the increase in sigma in the cement industry [4], heavy-duty manufacturing[5], food cans [6], the chemical industry [7].

All stages in DMAIC are interrelated in problem-solving. Define stage focuses on problem identification, process objectives, and identifying customer needs. Based on the problem can be identified the need or not of improvement steps. Problem identification can be made using Supplier, Input, Process, Output, Control (SIPOC) diagram and Critical to Quality (CTQ) determination. The use of SIPOC and six sigma can optimize process improvement [8].

The measure aims to understand and evaluate process conditions. Data collection and processing, control map creation, and calculating Defect per Opportunities (DPO), Defect per Million Opportunities (DPMO), and sigma levels are carried out at this stage. Process evaluation is done using an attribute control map, i.e., p-control chart. The calculation step of the p control map is as follows [3]:

1. Determine sample size
2. Determine subgroup k
3. Calculation of defect proportions

$$p = \frac{Total\ of\ defects}{number\ of\ sample/subgroup} \quad (1)$$

Where p is defect proportion/month, a total of defects/month, and number of sample/subgroup is production quantity/month (all is in pcs).

4. Calculation of the average products of defects

$$\bar{p} = \frac{(\Sigma\ defect/month)}{k} \quad (2)$$

Where p¯ is the average of defect product/year, Σ is the total of defects that occurred/year, k is the total of production quantity/year (all is in pcs).

5. Control limit calculation of p-charts

$$UCL = \bar{p} + 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n_i}} \quad (3)$$

$$CL = \bar{p} \quad (4)$$

$$LCL = \bar{p} - 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n_i}} \quad (5)$$

Where UCL is Upper Control Limit, LCL is Lower Control Limit, and ni is production quantity/month

DPMO is a measure of failure that shows the number of defects on one million occasions. Before calculating DPMO, DPO calculation is a measure of the number of defects per one occasion. Calculation formulas DPO, DPMO, and sigma level:

$$DPO = \frac{Total\ of\ Defect}{Total\ Unit \times CTQ} \quad (6)$$

$$DPMO = DPO \times 1.000.000 \quad (7)$$

$$Sigma\ Level = normsinv\left(\frac{1000000-DPMO}{1.000.000}\right) + 1{,}5 \quad (8)$$

The CTQ amount is 9 (types of defects) and normsinv is for sigma level calculation using Microsoft Excel.

Analyze is a step to improve understanding of the problem by identifying the cause and effect of the root cause of the problem. Identifying the root cause will be the first step to designing a solution that suits the existing problem. The tools used at this stage are Pareto diagrams to find out the most dominant types of defects, Apriori algorithms to identify combination relationships between interrelated defective items using if-then rules [9]. Apriori is one of the data mining techniques used for quality improvement integrated with six sigma. Data mining can be applied in all phases of DMAIC phase and how it can be deployed in real life environment [10]. Previous research has utilized data mining techniques in improving the quality of products[11] and service industry [12] .

R. Agrawal and R. Srikant in 1994 introduced apriori as seminal algorithm for mining frequent itemsets for Boolean association rules. This algorithm uses prior knowledge of frequent itemset properties. Apriori employs an iterative approach known as a level-wise search, where k-itemsets are used to explore (k + 1)-itemsets [9]. The strong rules is indicated by lift score >1. The combination that has a strong relationship rule indicates that the defective item needs to be repaired, and Fault Mode Effect Analysis (FMEA), which is a method for identifying potential failure modes that cause damage based on the calculation of Risk Priority Number (RPN) values.

Improve stage means to designing proposed improvements to reduce defective products. The improvement is expected to improve performance by increasing the sigma level so that the quality of the products is getting better. At this stage, 5W + 1H was used to find out more about the problem that occurs. The last stage in the Six Sigma approach is the control stage to monitor the impact after implementing the proposed improvement.

## 2. RESEARCH METHODOLOGY

Research methodology contents of research flow and data processing flowchart. Steps range from preliminary studies until conclusion withdrawal in the research flow, while data processing flowcharts contain flows from DMAIC research methods.

In the preliminary study, a visit to the company was made to discuss intentions, reasons for conducting research, how to spend research time, focus on research, and conduct interviews with the Quality Control department. Identification of problems was carried out after the observation process related to the Spun Pile production process. The observation process was carried out by observing the production floor or by online due to the condition of the COVID-19 pandemic. Interviews collected primary data (historical data and cause of defective products) and secondary data (general company data). Data processing uses the Six Sigma method with the DMAIC stage. Conclusions answer the study's purpose, including the results obtained during the study and the improvement proposal was given for further development in the future.

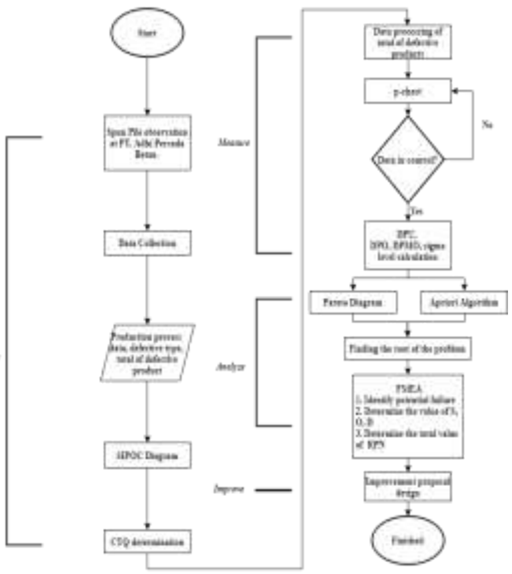


**Figure 1** Data processing flowchart

## 3. RESULTS AND DISCUSSION

### 3.1. Define

The defined stage is the initial stage of Six Sigma. in this stage SIPOC diagram was used (Table 2). This diagram identifies processes from raw materials to consumers, and the determination of Critical to Quality (CTQ) which is about fin fit, skin stickiness suitability, product integrity, product straightness, Spun Pile perfection, the product is not dented, non-porous product, Joint Plate Position, and the product is not cracked.

Figures and tables should be placed either at the top or bottom of the page and close to the text referring to them if possible.

### 3.2. Measure

At this stage, a p-chart was made after data collection had been carried out. P-chart was used in this stage because the defect in the Spun Pile product is an attribute defect (Figure 2). Data samples were from 100% of production results in January-December 2020. The number of samples varies depending on the good finished product during a month.

The p-chart shows that the process is under control. The next step DPMO was calculated and resulted the DPMO value is 617, which means there are 617 defective products in one million occasions, and the Sigma Level reaches 4.73 sigma (equivalent to the USA industry), which means it is very competitive but has not reached the world industry standard of 6 sigma. This is the background of the company's desire to be a better company by reducing the number of defective products.

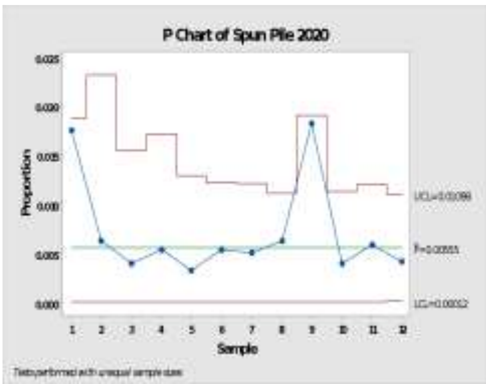


**Figure 2** P-chart 2020

**Table 2.** SIPOC diagram

| Supplier | Input | Process | Output | Customer |
|---|---|---|---|---|
| Raw Materials Supplier | PC Bar, Iron Wire, Joint Plate | Incoming Material Inspection | Inspection-passed material | Raw Material Warehouse |
| Raw Material Warehouse | PC Bar | PC Bar Cutting | Cutted PC Bar | Heading Machine |
| Heading Machine | Cutted PC Bar, Iron Wire | Forming | Frame Assembly | Inspection Area |
| Inspection Area | Frame Assembly | Forming Inspection | Inspection-passed Frame Assembly | Bottom Mold |
| Bottom Mold | Inspection-passed Frame Assembly | Frame assembly installation on the bottom mold | Installed-Frame Assembly | Bottom Mold |
| Bottom Mold | Installed-Frame assembly, Joint Plate | Joint Plate Setting | A Ready to Cast Frame | Molding Area |
| Molding Area | A Ready to Cast Frame | Prepare Inspection | Inspection-Passed Frame | Hopper Concrete Machine, Moulding Area |
| Hopper Concrete Machine, Moulding Area | Inspection-Passed Frame | Casting and Moulding Process | A Ready to Stress Product | Stressing Machine |
| Stressing Machine | A Ready to Stress Product | Stressing | A Ready to Spin Product | Spinning Machine |
| Spinning Machine | A Ready to Spin Product | Spinning | Spun Pile | Steaming Tub |
| Steaming Tub | Spun Pile | Steaming | Spun Pile | Cooling Area |
| Cooling Area | Spun Pile | Cooling | Spun Pile | Demoulding Station |
| Demoulding Station | Spun Pile | Demoulding | Spun Pile | Demoulding Station |
| Demoulding Station | Spun Pile | Post Pour Inspection | Inspection-Passed Spun Pile | Finishing Area |
| Finishing Area | Inspection-Passed Spun Pile | Finishing | Spun Pile | Stockyard |
| Stockyard | Spun Pile | Final Inspection | Spun Pile QC-Passed | Stockyard |
| Stockyard | Spun Pile QC-Passed | Storage | Spun Pile QC-Passed | PT. AdhiPersadaBeton |
| PT. AdhiPersadaBeton | Spun Pile QC-Passed | Shipping | Spun Pile QC-Passed | Customer |

### *3.3. Analyze*

The Analyze stage aims to identify the root cause of defects that occur in Spun Pile products. By knowing the root cause of the defect, you can design the appropriate improvement proposal. The tools used are the Pareto diagram, the Apriori algorithm, and FMEA.

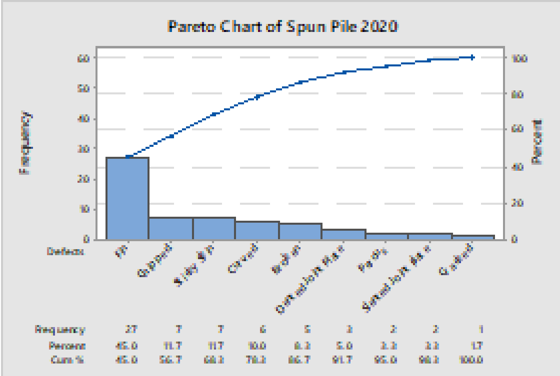


**Figure 3** Pareto diagram

The Pareto diagram shows that there are five types of defects: fin, chipped, sticky skin, curved, and broken, representing 80% of the Pareto principle during the Spun Pile production process from January to December 2020. In contrast to the Pareto diagram that identifies frequency, the Apriori algorithm is used to identify combination relationships between defective items that are interrelated using rules if-then rules. Rules that have strict rules indicate that the defective item needs to be repaired.

Several item sets were formed based on the dataset in Table 3. The result of the item set is in Tables 4, 5, and 6.

In forming 1 item set with a support value of 30%, items that meet the minimum support standard were obtained, namely items A, B, E, and I. In the combination of 2 items set combination of items that meet the support value of 30% namely AE, AI, BE, EI. The four combinations of items were formed again into 3 item sets. From the combination of 3 item set, no combination meets the minimum support value of 30%. The item set used is only a combination of 2 item sets and obtained a support value (minimum confidence of 70%), confidence benchmark, lift, and combination relationship for each item set on Table 7.

Apriori algorithm results were also tested using Tanagra software, and the results were the same as Table 4. There is one combination of items that have strong rules. Defect types A (sticky skin), B (gompal), E (fin), and I (curved) will be further investigated.

### *3.3.1. Fin*

Fins are part of a line on the side of the Spun Pile formed from the meeting of the upper and lower molds (Figure 5). Factors that cause defects in fins are the quality of bolts, such as rusty bolts and concrete residue on the bolt drat. This causes the bolts not to be appropriately attached. Less tight bolts can cause cement paste to come out of the molding gap during the spinning process.

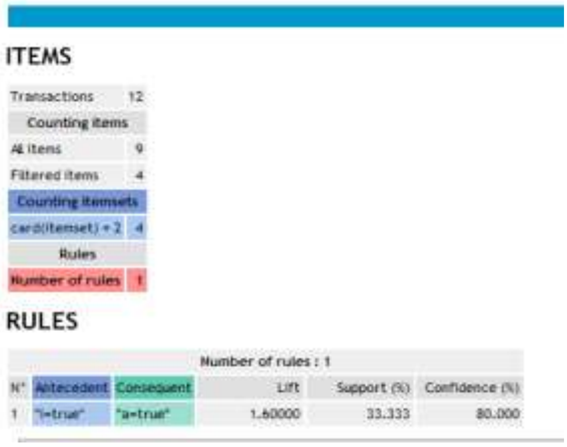


**Figure 4** Apriori algorithm with Tanagra

**Table 3**. Dataset

| No | Sticky Skin | Chipped | Porous | Cracked | Fin | Broken | *Slanted Joint Plate* | *Dented Joint Plate* | Curved |
|---|---|---|---|---|---|---|---|---|---|
| **Code** | **A** | **B** | **C** | **D** | **E** | **F** | **G** | **H** | **I** |
| 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 2 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 3 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 4 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 5 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| : | : | : | : | : | : | : | : | : | : |

**Table 4**. I temset

| 1 itemset | | |
|---|---|---|
| Min support 30% (0.3) | | |
| **Code** | **Count** | **Support** |
| A | 6 | 0.5 |
| B | 5 | 0.41667 |
| C | 2 | 0.16667 |
| D | 1 | 0.08333 |
| E | 11 | 0.91667 |
| F | 3 | 0.25 |
| G | 2 | 0.16667 |
| H | 2 | 0.16667 |
| I | 5 | 0.41667 |

**Table 5**. 2 Itemset

| 2 itemset | | | |
|---|---|---|---|
| Min support 30% (0.3) | | | |
| ∩ | | **Count** | **Support** |
| A | B | 3 | 0.25 |
| | E | 5 | 0.41667 |
| | I | 4 | 0.33333 |
| B | E | 4 | 0.33333 |
| | I | 3 | 0.25 |
| E | I | 4 | 0.33333 |

**Table 6**. 3 Itemset

| 3 itemset | | | | |
|---|---|---|---|---|
| ∩ | | **Combination** | **Count** | **Support** |
| AE | AI | A | 3 | 0.25 |
| | BE | ABE | 2 | 0.16667 |
| | HI | A | | |
| AI | BE | A | 2 | 0.16667 |
| | | AIE | | |
| | | IBE | | |
| | HI | A | | |
| HI | BE | BEI | 2 | 0.16667 |

**Table 7**. Combination relationship table

| Rules | Support | Confidence | Confidence Benchmark | Lift | Combination Relation-ship |
|---|---|---|---|---|---|
| If A, then E | 0.41667 | 0.83333 | 0.91667 | 0.90909 | Weak |
| If I then A | 0.33333 | 0.8 | 0.5 | 1.6 | STRONG |
| If B, then E | 0.33333 | 0.8 | 0.91667 | 0.87273 | Weak |
| If I then E | 0.33333 | 0.8 | 0.91667 | 0.87273 | Weak |

**Figure 5** Fin

### *3.3.2.* Sticky Skin

The surface of Spun Pile skin that shipped to the customer must be smooth, but sometimes there are defects in the skin. Defects in the skin of Spun Pile are called sticky skin defects(Figure 6). The man factor causes sticky skin, and the operator is less clean in cleaning the mold. This causes the remaining concrete in the mold in the previous production to stick to the Spun Pile. Molding oil was not resistant to steaming temperature because it is volatile and only lasts 1 x 24 hours, so the oil in the mold was uneven, and it must be smeared with oil again, resulting in delays in the production process. The method factor occurred when giving oil to the Spun Pile mold was uneven, and the temperature on the steaming tub was unstable.

**Figure 6** Sticky Skin

### *3.3.3. Chipped*

Chipped usually occurs during the molding process caused by material factors. If post-demolding handling is not done properly, then there will be a gompal defect (Figure 7). The cause of chipping was if there were any occurrence of severe sticky skin.

**Figure 7** Gompal

### 3.3.4. Curvy

The permissible limit is that Spun Pile products are not curved by more than 2% and are categorized as reject products. This type of defect is caused by material and machine factors. Based on Figure 4.30, machine factors are caused by poor molding quality; curved molding causes the product to curve (Figure 8). The temperature of the steaming tub is uneven and does not match the specifications, so when the Spun Pile was lifted for the concrete molding process, it was still unhardened, and the Spun Pile curves.

**Figure 8** Curvy

### *3.3.5.Broken*

Usually, a broken defect occurs (Figure 9) in Joint Plate because the quality of the bolt installed in the inner plate or end plate was not good. This caused by blunt bolt thread, so the bolt will lose and not be installed properly. This causes the Joint Plate to sink by the concrete so that the Joint Plate retainer breaks.

**Figure 9** Broken

### *3.3.6. FMEA*

FMEA is a tool used to identify the failure modes that have the most potential to cause harm. FMEA consists of processes, failure modes, the result of failure mode, failure causes, and controls that companies have already made to prevent failures. Severity, Occurrence, and Detection ratings are available to determine the Risk Priority Number. The defective type with the highest RPN value will be repaired. The FMEA result can be seen in Table 8.

Based on Table 8, it can be concluded that the value of defects that have the highest RPN value is in fin failure mode, sticky skin, and curved. RPN value of sticky skin failure mode with a value of 200 caused by a less clean mold, the second one was fin defect with an RPN value of 150 caused by bad bolt quality on the mold, and curved defect with RPN 140 caused by unhardened concrete.

## *3.4. Improve*

The potential fin, sticky skin, and curves were prioritized to be repaired based on analyze stage. The proposed improvements were carried out using the 5 W+1H (What, When, Where, Who, Why, How) method for each kind of defect. The proposed improvements are given in Table 9-10.

### *3.5. Control*

Control is the last stage in the DMAIC quality improvement approach, carried out to ensure that the results of the implementation of the proposal impact the performance of the process. Proposed improvement cannot be applied in PT. Adhi Persada Beton due to limited research time and the factory was in lockdown state.

## 4. CONCLUSION

Based on the analysis on the Spun Pile production process the DPMO of 617, and sigma level value of 4.73. Based on this criteria the improvement proposal will be evaluated.The Pareto diagram shows the dominant defect are fin, sticky skin, chipped, curved, and broken.Association rules in the Apriori algorithm are if A then E if I then A, if B then E, and if I then.  The rule that has a strong combination relationship is if there is a defect I (Curved), then there is a defect A (Sticky Skin) with a lift value of 1.6.In the FMEA method, there are three types of defects with the highest RPN value, namely sticky skin of 200, fin defects of 150, and curved defects of 140.Interrelated defects and defects with the highest RPN values were repaired.

**Table 8**. FMEA

| Process | Potential Failure Mode | Effect of Failure | S | Cause of Failure | O | Current Control | D | RPN |
|---|---|---|---|---|---|---|---|---|
| Spinning | Fin | Rework, Reject | 5 | Bad bolt quality on the mold | 6 | Replace bolts regularly | 5 | 150 |
| Prepare, Steaming | Sticky Skin | Rework | 5 | Less clean mold | 5 | Supervision by supervisor | 8 | **200** |
| | | | | Uneven oil pouring | 2 | Inspection during the preparing stage | 6 | 60 |
| | | | | Unstable steaming tub temperature | 4 | Checking the temperature of the steaming tub | 4 | 80 |
| De-moulding | Chipped | Rework | 6 | Concrete sticking to the mold | 6 | Doing grouting to fix the chipped part | 3 | 108 |
| Steaming | Curvy | Reject | 7 | Unhardened concrete | 4 | Set the temperature of the steaming tub according to the standard | 5 | 140 |
| | | | | Bad quality of molding | 4 | Periodic mold maintenance | 3 | 84 |

**Table 9**. 5W+1H Fin

| Fin | |
|---|---|
| What | Cleaning rust and crust on bolts with rust remover |
| When | Before the production process begins |
| Where | Molding area |
| Who | Molding operator |
| Why | So that the mold can be closed properly |
| How | Brushed or sprayed on the affected parts of rust and crust |

**Table 10**. 5W+1H Sticky skin

| Sticky Skin | |
|---|---|
| What | Mold cleaning form |
| When | After cleaning the molding |
| Where | Prepare area |
| Who | Molding operator |
| Why | The form is used to control the cleanliness of molds so that no sticky skin occurs. |
| How | The mold operator fills out the form after cleaning the mold by giving a checklist in the yes or no column according to the condition of the mold |

**Table 11**. 5W+1H Curved

| Curved | |
|---|---|
| What | Thermocouple |
| When | During the Steaming process |
| Where | Steaming tub |
| Who | Steaming operator |
| Why | Set the temperature of the steaming tub to be stable |
| How | The device will measure the temperature automatically |

The improvement proposal given to overcome fin defects due to rust and crust is the use of rust remover, sticky skin defects caused by less cleaned mold was by making mold cleaning forms and curved defects caused by unhardened concrete using Thermocouple on steaming tubs. The improvement proposal has not been implemented because the company is in a state of lockdown. For future work, the use of more data mining techniques should be explored in process improvement. Some predictive analytic algorithms can be used to predict product quality based on process variables. This will be very possible if the data collection process in the company can be carried out properly when the pandemic is over. The author hopes that the situation will improve and the pandemic will end soon.

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