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Implementation of DMAIC Six Sigma for Product Defect Analysis and Improvement Strategy

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ABSTRACT

This study focuses on a micro, small, and medium enterprise (MSME) operating in the rattan handicraft industry, which specializes in the production of home decor items such as plant stands. During the production of 9,000 Base Plant Stand units, the company recorded 2,305 defective products, resulting in a sigma level of 3.14. This study aims to identify the root causes of product defects and propose effective process improvement strategies using a combination of qualitative and quantitative approaches. The research employed the DMAIC (Define, Measure, Analyze, Improve, Control) methodology of Six Sigma to analyze production data and determine key defect categories. The dominant defects identified were mold (27.9%), imprecision (22.7%), and loose ties (20.9%). Root causes included high humidity levels, suboptimal oven performance, limited workspace, and insufficient operator skills. Based on direct observations and literature studies, proposed improvements include covering products during rain, measuring and managing moisture content, conducting routine oven maintenance, expanding WIP (Work-in-Process) areas to prevent excessive stacking, and developing clear, detailed SOPs. These actions aim to enhance production quality and raise the company's sigma level through continuous improvement. This study serves as a reference for optimizing defect reduction efforts in MSME-scale rattan production.

Keywords: *Six Sigma, DMAIC, Quality Control, Product Defect, Rattan Handicrafts*

Introduction

Industry Furniture and furniture made from Indonesian rattan is one of the potential products that are in demand by the global market, such as Canada. Statistical data shows that in 2021 the value of rattan imports to Canada increased by 48.2% from the value of imports in 2020. In 2022, rattan from Indonesia dominates 80% of the global market supply, this happens because Indonesia's nature is very suitable for this type of plant, so it has an abundant availability of raw materials, including meranti wood, teak, mahogany, and acacia.[1], [2]

The many business opportunities in the rattan handicraft sector have led to increased competition between producers. At this time, consumers are very selective in choosing and buying the products they need, for that reason the quality and price of products are the main things that consumers will compare with competitors. This requires the company to use the right strategy with the least possible mistakes so that the products produced are of good quality and the company's profits are maximized.

Sumber Sejahtera Rattan is an MSME in Cirebon Regency engaged in the rattan handicraft sector which started its business in 2005. At the beginning of its business, Sumber Sejahtera Ratan only accepted orders for the production of chair and table frames, then over time, this company developed and innovated by producing other products. The resulting product is in the form of a good semi-finish which is then finished and packaged by the supplier before being sent to the buyer. Currently, Sumber Sejahtera Rotan has 42 employees divided into five divisions, namely cutting-steam, framing, decorating, weaving, and finishing. The resulting crafts are in the form of plant pots, chairs, tables, and storage boxes which can be seen in Figure 1.

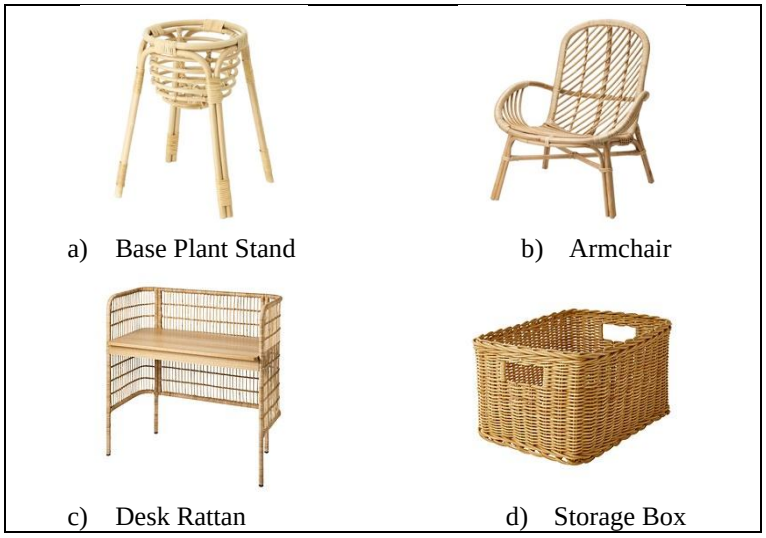

Figure 1. Sumber Sejahtera Rattan handicraft products

Sumber Sejahtera Rattan uses a make to order system, which is a production system that produces goods if there is an order. The product that is the focus of discussion in this study is the Base Plant Stand which can be seen in Figure 1a. The product has a demand of 9000 units within nine weeks, namely the period of September – October 2024. The demand was solved by scheduling production of 1000 units per week, with defects of 2305 units out of 9000 units produced. Some of the types of defects that occur are mold, pinholes, imprecision, loose ties, and flames. The distribution of product defects is as follows:

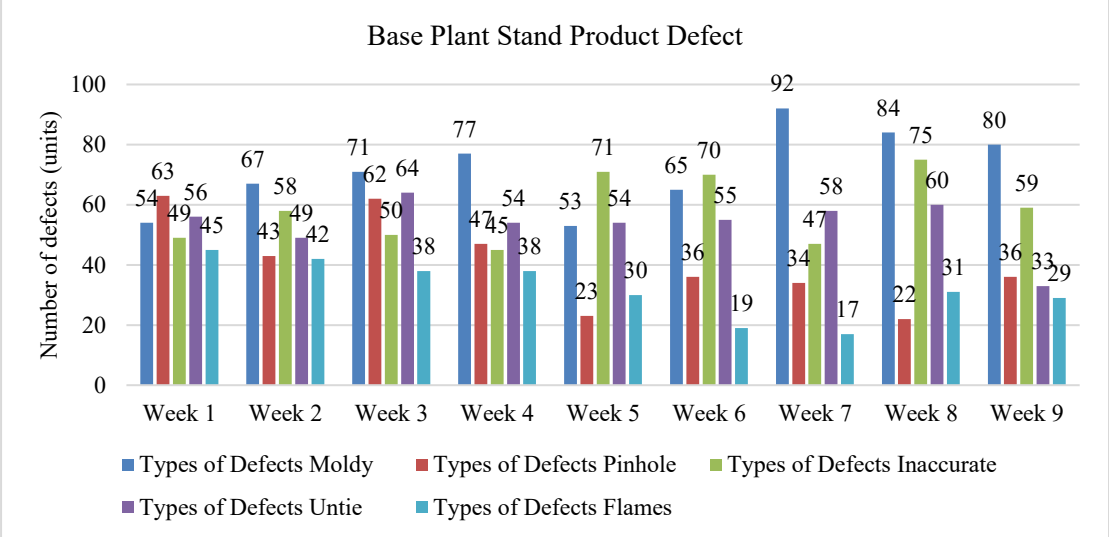

Figure 2. Base Plant Stand product defect

In Figure 2, it can be seen that every production per week, there is always a product defect with fluctuating quantity. Product defect data Base Plant Stand It was used to measure the sigma value, and a sigma value of 3.14 was obtained. Based on several studies in the last five years, the company's sigma value that is still at level 3 can be increased to approach the sigma value of 5 or 6. According to, rattan chair production craft companies that have a sigma value of 3.31 can make improvements with a method approach Six Sigma DMAIC. According to[3], companies that have a sigma value of 3.00 in the production of rattan chairs can make improvements with a method approach [4] Six Sigma DMAIC. According to, craft companies that produce rattan chairs with a sigma value of 3.49 can carry out production efficiency with the [5] Six Sigma DMAIC. In other industries, efforts to minimize product defects by implementing Six Sigma DMAIC is also able to increase the sigma value, the research can increase the sigma value of 3.47 to 3.62. Based on previous studies, the problems that exist in Sumber Sejahtera Rattan regarding product defects can also be solved by using the [6] Six Sigma DMAIC. The

research carried out includes analysis, evaluation of the causes of problems, proposals in the form of improvement efforts and control by the Lean Six Sigma using the DMAIC phase concept to minimize defective products and increase the company's sigma value so that it can improve customer quality. DMAIC is a stage carried out in undergoing any repair project, which stands for define-measure-analyze-improve-control. DMAIC is a process closed-loop which eliminates unproductive process steps, often focuses on new measurements and implements technologies for quality improvement towards the target Six Sigma.[7]

Research Methods

The research was conducted at Sumber Sejahtera Rattan to analyze the number, proportion, causes of defects, and proposed improvements in the Base Plant Stand product through several stages, namely case studies, problem identification, observation, data collection, data processing, analysis, and conclusions according to the following flow chart:

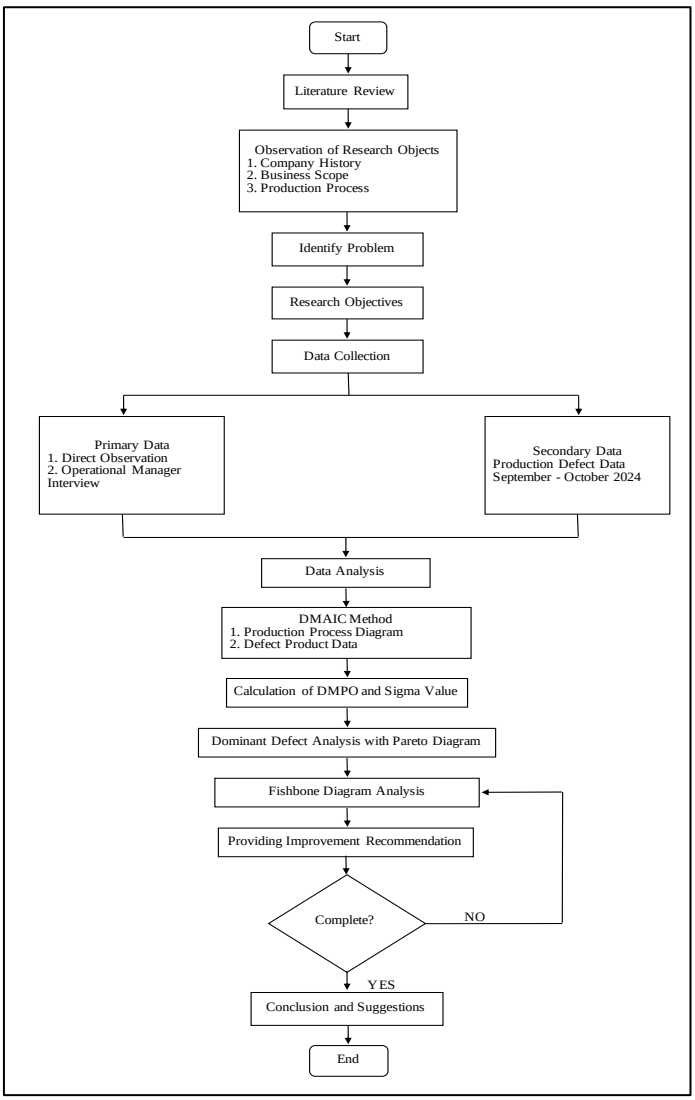

Figure 3. Flow chart of research methods

Six Sigma

Six Sigma is a comprehensive and flexible system to achieve, support or optimize a business process that focuses on customer needs by utilizing data, facts, and statistical analysis and by paying attention to the continuous management, improvement, and review of processes in a business. Six Sigma is a vision of quality improvement towards the target of 3.4 failures per 1,000,000 (million) opportunities

(DPMO-defects per million opportunities) for every transaction of products (goods and/or services) or the swamp is active towards excellence (zero defects-zero failure) [8]. According to [9], [10] Six Sigma is a holistic approach to solving problems and improving processes through DMAIC.

Table 1. DPMO and sigma level

Specification Limits (LSL - USL)	Percentage that meets specifications (LSL - USL)	DPMO (failures/defects per million opportunities)
± 1-sigma	68,26%	317.300
± 2-sigma	95,46	45.500
± 3-sigma	99,73%	2.700
± 4-sigma	99,9937%	63
± 5-sigma	99,999943%	0,57
± 6-sigma	99,9999998%	0,002

The classification of sigma values based on DPMO values can be seen in Table 1. The DPMO value obtained depends on the number of defective products, the total products produced, and the CTQ (Critical to Quality). CTQ identification is developed from specifications sourced from voice of costumer and the company's existing specification standards. Desired product [11] costumer is a product that meets the specifications, which does not have such defect criteria. Here's how to determine the DMPO value:

$$\mathbf{DPMO} = \frac{\mathbf{number\ of\ defective\ product}}{\mathbf{number\ of\ products\ produced\ x\ CTQ}} \mathbf{x\ 1.000.000} \quad (1)$$

After obtaining the DPMO value, then the value is converted to a sigma value based on the sigma conversion table.

Lean Six Sigma

In undergoing the process, Lean Six Sigma can be used to systematically reduce defects with DMAIC. By defining (define), Measurement (measure), Analysis (analyze), Repair improve), and control (control) [12]–[14]

- Define is the initial stage that aims to determine the problems that exist in the company and identify the products to be improved. This stage is carried out by explaining the production flow, identifying the process flow from supplier to customer using SIPOC (Supplier, Input, Process, Output, Customer) diagrams [15].
- Measure is the second stage which aims to calculate sigma values based on data on the number of productions, number of defects, CTQ, and DPMO calculations [16].
- Analyze It is an analysis stage to analyze the dominant defect by using a Pareto diagram to find out the largest defect in order and identify the causes of the defect using fishbone. Diagram fishbone is a tool used to display data on the causative factors of defects or non-conformities, to analyze into the deepest sub-sub-factors of the factors that cause problems. Diagram [17], [18] fishbone It is shaped like a fish bone that contains five factors that cause disability, namely humans, methods, materials, machines, and the environment.
- Improve It is a stage to make improvements to the causes that have been identified through the previous stage. Contains the development of an action plan that is expected to eliminate existing problems. Phase improve is a set of activities to determine, select, and select several alternative remedies (improvement) to improve the company's performance. 5W+1H Principle [19] (what, when, who, where, why, how) carried out in stages improve as a proposal for improvement.[20]
- Control is the last operational stage in improving the quality of Six Sigma and there is continuous improvement.

Results and Discussion

The data used is secondary data, namely data on the number of production and defective products in CV Sumber Sejahtera Rotan.

1. Define

Define is the stage of identifying the production process Base Plant Stand using the help of SIPOC diagrams as can be seen in Figure 4, aiming to find out the flow of the production process in the company. The following is a diagram of the SIPOC production process Base Plant Stand at Sumber Sejahtera Rattan:

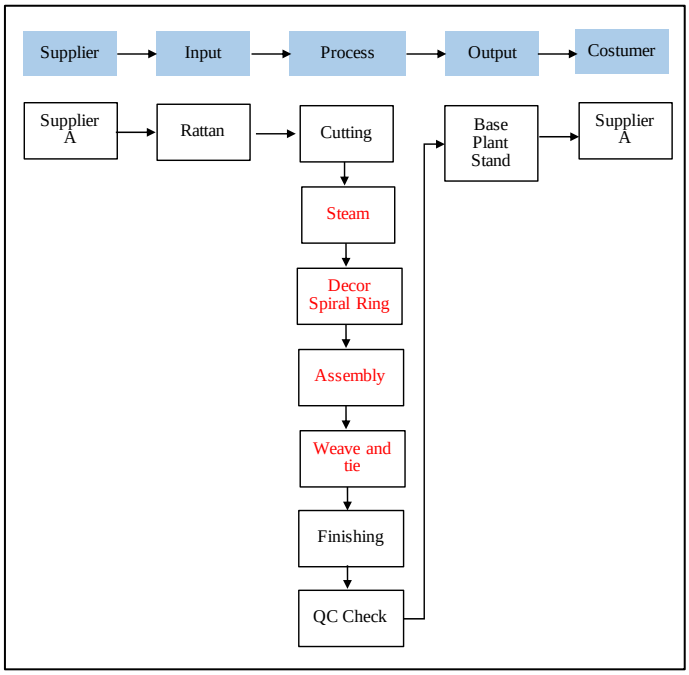

Figure 4. Diagram SIPOC

During the production process from the stage Cutting until Finishing prone to find several defects that occur, especially in the process Steam, decoration, assembly body, and ikat weaving process. At this stage, the goals and targets of improvement that are the object of research are determined, namely the number of defective products Base Plant Stand. The conditions that can be given to consumers are products that meet the standard specifications and are free from defects.

2. Measure

DPMO and Sigma Value

Table 1. DPMO and sigma values Base Plant Stand

No	Frequency	Production Quantity	Total Defects	CTQ	DPMO	Sigma
1	Week 1	1000	267	5	53400	3,11
2	Week 2	1000	259	5	51800	3,13
3	Week 3	1000	285	5	57000	3,08
4	Week 4	1000	261	5	52200	3,13
5	Week 5	1000	231	5	46200	3,18
6	Week 6	1000	245	5	49000	3,16
7	Week 7	1000	248	5	49600	3,15
8	Week 8	1000	272	5	54400	3,10
9	Week 9	1000	237	5	47400	3,17
Average			256			**3,14**

The calculation of the DPMO value is carried out using the following formula:

(2)

For Week 1 Calculation

$$\mathbf{DPMO} = \frac{\mathbf{267}}{\mathbf{1000\ x\ 5}}\ \mathbf{x\ 1.000.000} = \mathbf{53400}$$

The DPMO value was obtained as 53400, then the sigma value was determined based on the sigma conversion table. The calculation is as follows:

$$\mathbf{y} = \mathbf{y1} + (\mathbf{x} - \mathbf{x1})\ \frac{\mathbf{y2} - \mathbf{y1}}{\mathbf{x2} - \mathbf{x1}}$$

$$\mathbf{y} = \mathbf{3,2} + (\mathbf{53400} - \mathbf{44600})\ \frac{\mathbf{3,1} - \mathbf{3,2}}{\mathbf{54800} - \mathbf{44600}}$$

$$\mathbf{y} = \mathbf{3,2} + (\mathbf{8800})\ \frac{\mathbf{-0,1}}{\mathbf{10200}}$$

$$\mathbf{y} = \mathbf{3,2} + (\mathbf{-0,08627451})$$

$$\mathbf{y} = \mathbf{3,11}$$

Using the same calculation formula, the recap data for the calculation of DPMO and sigma values for Base Plant Stand production is obtained as shown in Table 2. The data shows that the average product defect during the nine weeks of production is 256 products and a sigma value of 3.14 is obtained. Referring to Table 1, the sigma value of 3.14 is included in the classification of 99.73% of production that meets the specifications, meaning that the sigma value can still be improved with continuous improvement.

3. Analyze

Diagram Pareto

A Pareto chart is a bar chart that shows a problem based on the order of its problems starting from the most frequent to the least occurring. Defect sequence with the highest frequency in production [21]Base Plant Stand in Sumber Sejahtera Rattan are as follows:

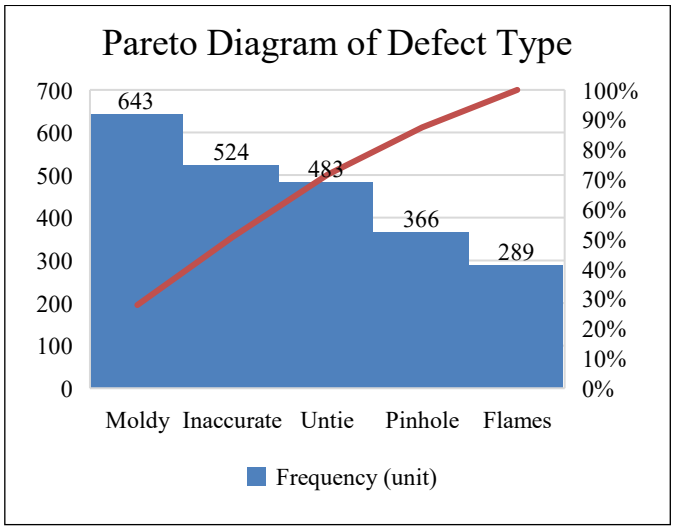

Figure 5. Cumulative pareto diagram

Based on Figure 5 where the determination of the type of defect follows the 20:80 rule on the principle of the pareto diagram. The data on the highest defect types is sorted from right to left to identify potential problems that need to be fixed. There are three dominant types of defects, namely mold (27.9%), imprecision (22.7%), and loose ligament (20.9%) where each percentage of defects has exceeded 20% of the total defects that occur. Next, an analysis of the causes of the disability was carried out using the help of a diagram fishbone to identify the root cause of each CTQ [22]

Fishbone Diagram

The dominant defects determined based on the pareto diagram are then analyzed using a diagram fishbone. After doing Brainstorming with operational manager, the factors that cause the defect are as follows:

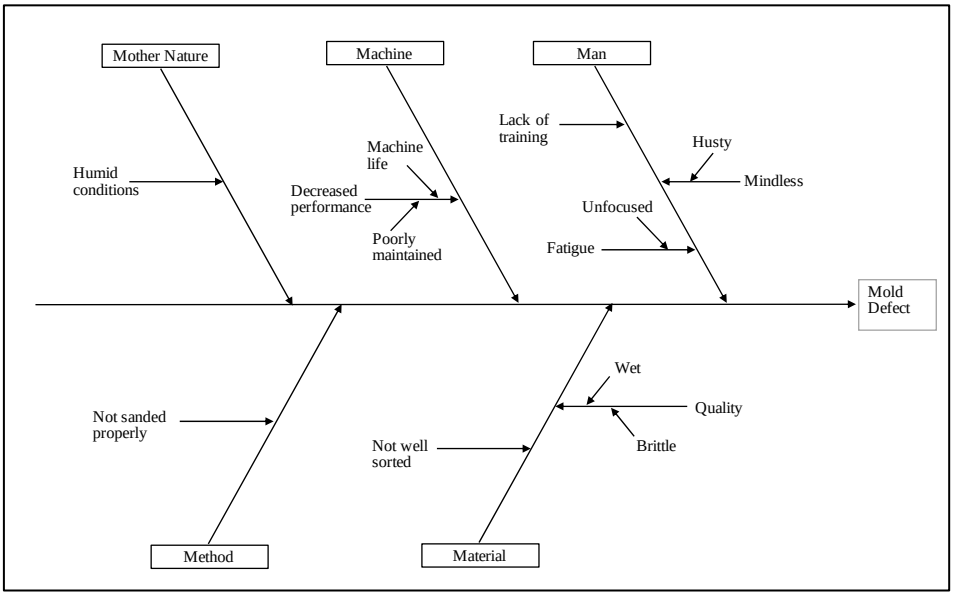

Figure 6. Diagram fishbone mold defects

Mold on rattan causes rattan to become regas or rotten. Based on Figure 6, several factors cause moldy defects. The main factors that cause mold defects are humid conditions and less than optimal oven performance. Humid conditions can be caused by weather factors, namely rattan being wet with rainwater, this can be found when it is still raw material or work in process (WIP). For raw materials, excess moisture content can be removed during the drying process with ovem, but the poorly maintained condition of the oven causes unstable temperatures so that the drying process is not optimal. Currently, there are no stages of measuring moisture content in rattan.

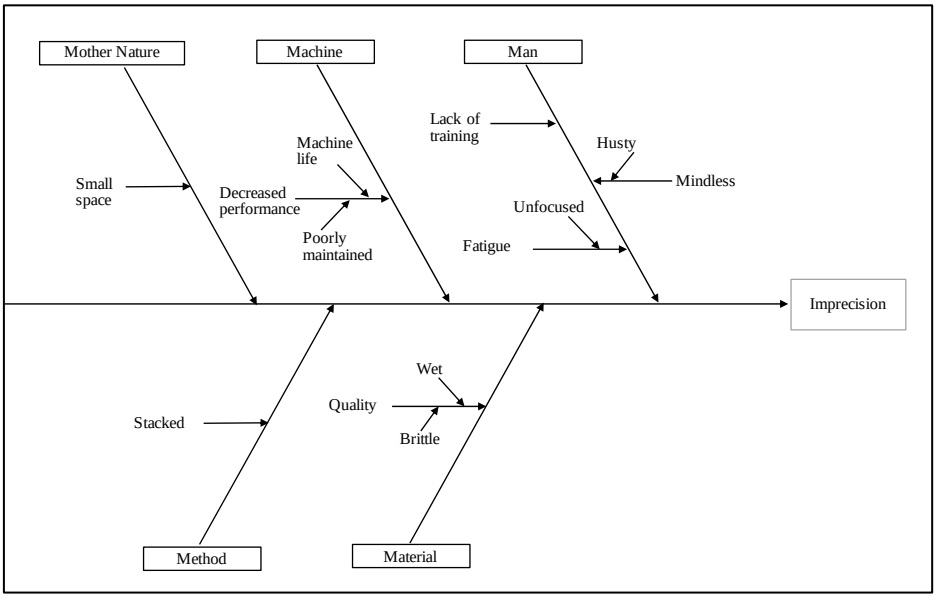

Figure 7. Diagram fishbone imprecision defects

The resulting product is not precise is the second most defect that occurs in the production of Base Plant Stand. Based on Figure 7, the main factor causing imprecision defects is a small space that causes the operator to store WIP by piling up, and if there are many products, the pile is getting higher causing the product below to get high pressure so that the product becomes imprecise.

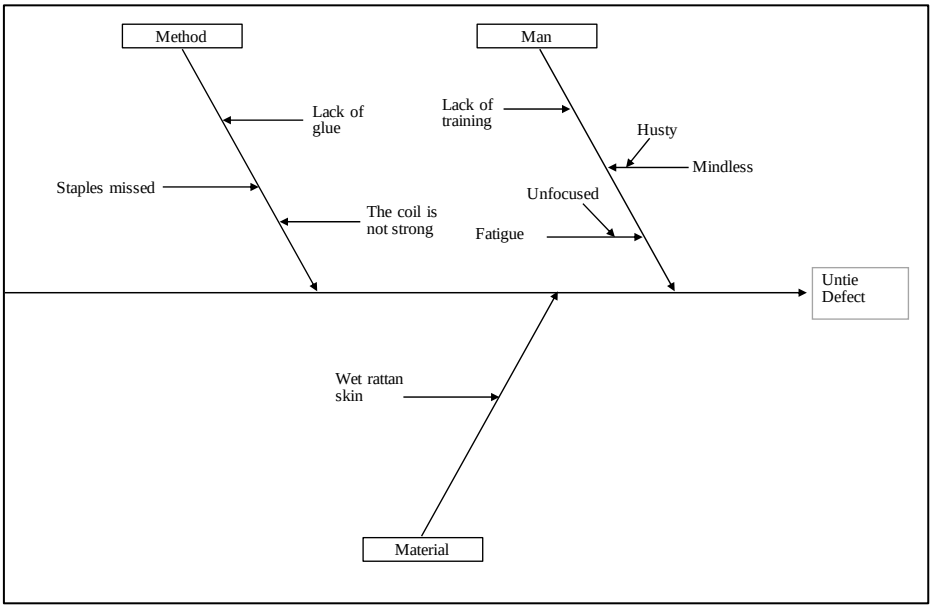

Figure 8. Diagram fishbone unties defects

Figure 8 explains that the occurrence of loose bond defects is caused by three factors. The main factor is that the operator misses firing the steples during the framing process, less glue and less strong winding during the weaving process.

4. Improve

After conducting an analysis and obtaining the factors that cause the defect, here are suggestions for improvements that can be made at Sumber Sejahtera Ratan to optimize the Base Plant Stand production process[23]:

What

The description is what is the main target of improvement or quality improvement.

Answer :

1. Reduces mold product defects due to humidity and oven performance factors
2. Reduces imprecision defects due to tight space
3. Reduced loose tie defects due to lack of operator skills
4. Optimize the production process

Proposal:

1. Create Standard Operational Procedures (SOPs) related to the production process in detail and easy to understand
2. Create SOPs for tools used during the production process
3. Measuring moisture content using a measuring device
4. Perform oven maintenance and regular checks to ensure optimal oven temperature
5. Provides a wider work-in process space so that products are not stacked too high
6. Provide training to operators to improve their capabilities and provide the same standards between operators, from the process of handling raw materials to finishing
7. Conduct regular evaluations with operators regarding product defects so that repeated errors do not occur
8. Ensure the working environment, especially the storage of raw materials and products is not damp. You can cover the product with a tarpaulin if the weather is rainy
9. Provides rest instructions so that the operator does not over-fatigue while working

Why

The description is why the action plan needs to be carried out

Answer :

1. To increase the level of consumer satisfaction
2. To reduce product defects because product defects can add to production costs and time
3. Increase the company's sigma value

Proposal:

1. Conduct repeated supervision and checks
2. Be more thorough when performing all stages of production

Where

The description is where the plan of action will be carried out

Answer: in each division of Sumber Sejahtera Rattan

Proposal: training to check raw materials to finished products, from the stage of receiving raw materials to Finishing with checks including color, shape, webbing, nails, and neatness of the joints

When

The description is when the action plan activities will be carried out

Answer: repairs are made as soon as possible

Proposal: The faster the repair is made, the faster the problem will be resolved, accompanied by regular audits

Who

The description is who will carry out the action plan activities

Answer: applied to all production operators and policy holders as policy makers

Proposal: All employees of the company remind each other, evaluate, and provide suggestions for improvement if there is an error during the production process

How

The description is how to carry out the action plan activity

Answer: Repairs are carried out by all employees of Sumber Sejahtera Ratan continuously

Proposal: Periodic monitoring is carried out accompanied by good documentation, if errors are found, an evaluation is immediately carried out which is followed by all employees so that information is spread evenly in the hope that the same and repeated errors do not occur.

5. Control

Control is the last stage of DMAIC. The control phase focuses on how to keep improvements going, including putting the device in place to ensure that the key variables remain within the maximum acceptable territory in the process being modified. This research was not carried out until the stage of comparing sigma values before and after it was carried out [24], [25] Improvement However, the proposal given is expected to reduce the number of product defects and increase the value of Sigma. Phase Control done with the company implementing the system continuous improvement so that the company can maintain stability Output products so that out of specification, and if it is found that there is a defect Therefore, the company controls production from the factors of machines, people, methods, and materials. Phase Control It is necessary to do documentation so that repeated errors do not occur and statistical tools are needed in terms of quality control. Stages Control affirming for the documentation and dissemination of actions[26], [27]

Conclusion

The data used in this study is data on product defects that occurred during the production of 9000 Base Plant Stand products during the period of September-October 2024 (nine weeks) and 2305 products were found to be defective. Defects were found in the form of mold, pinholes, loose ties, imprecision, and flames. Cause analysis was carried out on the dominant defects, namely moldy defects, imprecision, and loose ligaments. From the results of the study, it was found that the main factors were humid conditions, suboptimal oven performance, small space, and lack of operator skills. Based on these factors, to reduce product defects and increase sigma values, improvement proposals are given for dominant defects in the form of covering products with tarpaulins during rainy weather, checking moisture content with measuring instruments, maintaining and checking the oven periodically to ensure that the temperature remains optimal, adding space for WIP so that products are not stacked too high, and making SOPs for tools and production processes in detail and easy to understand.

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