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Improvement Proposal Of Welded Wire Mesh Production Process In PT HBU Using FMEA And Six Sigma With DMAIC

Arda Kevin Revialdy Handoko [1), Yuanita Handayati [2)
[1,2) Master of Business Administration Institut Teknologi Bandung
Email: [1) kevin_revialdy@sbm-itb.ac.id , [2) yuanita@sbm-itb.ac.id

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ABSTRACT

This research aims to identify and provide alternative solutions as an effort to reduce defects in the welded wire mesh production process at PT HBU using the Six Sigma approach integrated with Failure Mode and Effect Analysis (FMEA). This research was carried out by applying the DMAIC (Define, Measure, Analyze, Improve, Control) framework to improve product quality and process efficiency. In the Define stage, key problems are identified, and improvement objectives are set. The Measure stage includes data collection and initial analysis to measure the existing defect rate using the Defect per Million Opportunities (DPMO) and Sigma Level metrics. Furthermore, in the Analyze stage, root causes are identified and analyzed using Cause-and-Effect Diagram. In the Improve stage, FMEA is used to analyze the potential causes of defects by determining their priority and proposing improvement solutions based on the previous analysis to be implemented as an effort to reduce the possibility of defective products in the production process. Finally, in the Control stage, a schedule is designed for the implementation of the proposed improvements provided. The implementation of this integrated approach is expected to reduce the defect rate in products, improve product quality, and improve overall operational efficiency.

INTRODUCTION

Indonesia, a Southeast Asian archipelago with the fourth largest population globally, has a burgeoning manufacturing industry that significantly contributes to its economic growth. According to Statista (2022), manufacturing is the number one industry in Indonesia according to their contribution to GDP in 2023.

The rapidly growing industrial segments such as manufacturing and construction industry has led to rising demand for welded wire mesh. As mentioned above, there was also an increase in use of welded wire mesh products, especially in the construction, manufacturing, and mining industry. The manufacture, distribution, and use of the products are the focal points of the

Welded Wire Mesh market, a subset of the manufacturing and construction sector. In 2023, the market size of welded wire mesh products was valued at 5.8 billion US Dollar and is expected to reach 7.8 billion US Dollar by the end of 2030 according to Verified Market Reports (2024). A forecast conducted by GlobeNewswire (2024) states that from 2024 to 2032, the global wire mesh market is projected to witness substantial growth and is being supported by an increasing demand from the construction, industrial, and agricultural sectors. The comprehensive market analysis reveals a forecasted CAGR of 4.9%, attributed to the expansion in urban development and infrastructural activities.

Welded Wire Mesh (WWM) is a prefabricated grid or network of intersecting metal wires that are welded together at their points of intersection. The wire mesh is often associated with its intrinsic qualities of high strength, durability and affordability as shown in Figure I.2. It has become a crucial material, reinforcing concrete and offering structural stability in a variety of applications, as used in construction, agriculture, infrastructure development, and industrial processes. PT HBU is one of the companies in Indonesia that provides various kind of welded wire mesh products. It is a private company specialized in manufacturing high quality welded steel wire mesh for various applications. The increasing global demand for welded wire mesh has put a lot of pressure on the companies to increase production while at the same time maintaining the quality of the products and being committed to sustainable practices.

Therefore, it is very important for PT HBU to put more effort into maintaining their competitive advantage and their market. Creating a production to be as efficient as possible seems to be an effective solution to overcome the possible increasing market size nationally or even globally.

LITERATURE REVIEW

Six Sigma Quality

According to The Council for Six Sigma Certification (2018), Six Sigma is a methodology for process improvement and a statistical concept that seeks to define the variation inherent in any process. The Six Sigma methodology aims to decrease variation and error opportunities, which in result reduces process costs and increases customer satisfaction. According to Jacobs and Chase (2018), Six Sigma is a statistical term to describe the quality goal of no more than 3.4 defects out of every million units. According to Simchi-Levi, et al (2021), Six Sigma is a statistical term to describe the quality goal of no more than 3.4 defects out of every million units.

Table 1 Levels of Sigma (The Council for Six Sigma Certification, 2018)

Sigma Level	Defects per Million Opportunities (DPMO)
One Sigma	690,000
Two Sigma	308,000
Three Sigma	66,800
Four Sigma	6,200
Five Sigma	233
Six Sigma	3.4

Defects per million opportunities, or DPMO, is a metric used to describe the variability of a process (Jacobs and Chase, 2018). This metric commonly requires three kinds of data, namely: Unit, Defect, and Opportunity. Here, a Unit is described as the item produced or being served. Then, a Defect is described as any item or event that does not meet the customer's requirements. Also, an Opportunity is described as a chance for a defect to occur. The DPMO and Sigma Level calculation can be examined using the following formulas.

DPMO = (Number of defects)/(Number of opportunities × Number of units) x 1,000,000
Sigma Level = NORMSINV(1-DPMO/(1,000,000)) x 1.5

METHODS

Six Sigma DMAIC

In the context of Six Sigma, the method known as DMAIC offers a systematic framework that organizational members adhere to when addressing problems and enhancing processes, in which by following this structured approach, individuals can prevent premature conclusions and ensure a thorough exploration of alternative solutions (Schroeder, et al., 2008). Jirasukprasert et al. (2014) outline the Six Sigma and DMAIC framework consists of five-step processes, that are: Define, Measure, Analyze, Improve, and Control.

1. Define Phase: This stage includes identifying the project team and their roles, establishing the project's scope and boundaries, understanding customer requirements and expectations, and setting specific goals for the project (Jirasukprasert et al., 2014). The first stage of the Six Sigma and DMAIC's methodology is "define." This stage aims at defining the project's scope and boundary, identifying the voice of the customer (VOC) and goals of the project (Gijo et al., 2011).
2. Measure Phase: This stage involves selecting measurement factors that will be improved and providing a structure for evaluating existing performance as well as assessing, comparing, and monitoring subsequent improvements and capabilities (Jirasukprasert et al., 2014). The "measure" phase of the DMAIC problem-solving methodology consists of establishing reliable metrics to help monitoring progress towards the goals (Pyzdek, 2003).
3. Analyze Phase: This stage focuses on determining the root cause of the problem (defect), to understand why the defect exists and to compare and prioritize opportunities for better further improvement (Jirasukprasert et al., 2014). This phase in the DMAIC improvement model involves the analysis of the system to identify ways to reduce the gap between the current performance and the desired objectives (Garza-Reyes et al., 2010) (Jirasukprasert et al., 2014).
4. Improve Phase: The stage focuses on generating possible improvements to reduce the amount of quality problems and/or defects. This often involves experimenting and using statistical tools (Jirasukprasert et al., 2014).
5. Control Phase: The final stage focuses on ensuring that the improvements made are sustained over time. Ongoing performance is also monitored, and the improvement process is documented and institutionalized (Jirasukprasert et al., 2014). The aim of the control phase is to sustain the gains from processes which have been improved by institutionalizing process or product improvements and controlling ongoing operations (Jirasukprasert et al., 2014).

Failure Mode And Effect Analysis (FMEA)

FMEA is a systematic method to map failure modes, effect and causes of technical systems (Peeters et al., 2018). The FMEA approach is useful for revealing the components, failure modes, and root causes of failure that are most relevant for system reliability and availability, and for identifying suitable preventive actions (Fischer, K., et al., 2012). According to Arabian-Hoseynabadi, et al. (2010), the FMEA is also useful for considering design improvements for technologies that are subject to changes or upgrades.

According to Peeters et al. (2018), a purely qualitative FMEA can be extended to be a more detailed-quantitative approach by adding the criticality aspect to each failure mode that is quantified using the risk priority number (RPN). There are three fundamental indicators or attributes used in the FMEA method to calculate the RPN, that are the occurrence level (O), the severity level (S), and the failure-detectability level (D) (Wan C., et al., 2018 & Peeters et al., 2018).

1. The occurrence level of failure refers to its failure frequency and is rated from very unlikely to occur to almost inevitable (Peeters et al., 2018).
2. The severity level of failure refers to the seriousness of the effect or impact of a certain failure and is rated from low impact to very high impact (Peeters et al., 2018).
3. The detectability level of failure refers to the likelihood that the failure is not detected before it induces major subsequent effect (Peeters et al., 2018).

The detectability indicator is rated from almost sure detection to almost non-detection. Furthermore, to calculate the RPN, the three indexes for severity, occurrence, and detectability must be multiplied by each other (where RPN = S x O x D), which implies that each index is equally important.

Data Collection Methods

The selection of a specific method is based on its alignment with the context and objectives of the research, to ensure the relevant data is obtained from various sources. These methods encompass in-depth interviews with key stakeholders, focus group discussions, historical data, and direct observation.

Data Analysis Methods

To address the business issue, the theoretical framework's proposed model has been structured into five phases of DMAIC (Define, Measure, Analyze, Improve, and Control). An elaboration of these five stages of methodology can be seen as follows.

1. Define Phase: the data analysis tool to be used is RACI Matrix (Responsible, Accountable, Consulted, Informed) and SIPOC Diagram (Supplier, Input, Process, Output, Customer). The RACI Matrix is used to describe the relationship between jobs, determine the roles, responsibilities, and levels of authority for each activity in the project (Suhanda & Pratami, 2021). Furthermore, a SIPOC diagram analysis is used to define the input and output variables from a process, and the stakeholders involved.
2. Measure Phase: the data analysis tools that will be used are Process Control Chart and Pareto Chart. A control chart used to monitor the proportion of defective units in a process is the P-Chart. On the other hand, a control chart used to monitor the defects per unit in a process is the U-Chart. While the Pareto Diagram helps breakdown the problem, showing the proportional impact of each contributing factor. It is based on the 80/20 rule, where a small number of causes often account for most of the problem.
3. Analyze Phase: the data analysis tools that will be used is Fishbone Diagram, which also known as Cause-and-effect diagram. After creating the diagram, the analysis would focus on identifying which potential causes are actively contributing to the problem.
4. Improve Phase: the data analysis tools that will be used is Failure Mode and Effect Analysis (FMEA). The FMEA analysis is applied to analyze the linkage between the potential failure modes and prioritizing it using Risk Priority Number (RPN).
5. Control Phase: the data analysis tools that will be used is Gantt Chart. It is used to define the activities and schedule the implementation planning of the proposed improvements in this research.

RESULTS

Stakeholder Analysis

This study uses the RACI table on Table below breaks down the key activities in welded wire mesh production. Each activity is assigned to a stakeholder who has direct responsibility

(Responsible - R), who holds full accountability (Accountable - A), who needs to be consulted (Consulted - C), and who should be informed (Informed - I).

Table 2 RACI Matrix For Stakeholder Analysis

Activity	R	A	C	I
Drawing & Cutting Process:				
Interpreting technical drawing	Operator	Production Supervisor	Manufacturing Manager	Quality Control (QC) Supervisor
Selecting appropriate materials	Operator	Production Supervisor	Manufacturing Manager	QC Supervisor
Operating cutting machines to cut materials	Operator	Production Supervisor	Manufacturing Manager	QC Supervisor
Welding:				
Operating welding machines and performing welding tasks	Operator, Daily Workers	Production Supervisor	Manufacturing Manager	QC Supervisor
Inspecting welding quality	QC Department	Production Supervisor	Manufacturing Manager	Production Supervisor

SIPOC Analysis

This study also uses SIPOC analysis table for the production department is designed to map out the Suppliers, Inputs, Process, Outputs, and Customers, aims to offer a comprehensive understanding of the production process from start to finish.

Table 3 SIPOC of Production Department

Supplier	Input	Process	Output	Customer
Sales department	Work order document (WO)	Shown in Table 4	Raw material unavailability report	Sales department
	Pipe for fabrication		Finish goods	Warehouse inventory
	Work drawings		Production report	Quality control department
	Fabrication equipment			

Table 2 Production Process Steps

Step 1	Step 2	Step 3	Step 4	Step 5
Preparing	Drawing, Marking, and Cutting	Setting & Checking	Welding	Finishing, Packing, Weighing & Labeling

A descriptive explanation of the production process steps of welded wire mesh products shown in Table 4 can be seen as follows.

1. Preparing: Receive WO from the sales department which includes product specifications, and other details. Then, the production preparation steps are carried out by checking the availability of pipe stock as raw materials, studying the working drawings for the fabrication process, and preparing the fabrication equipment.
2. Drawing, Marking, and Cutting: The wire rod pipe is reduced in diameter by being pulled into a larger hole to increase density, tensile strength, and yield strength. Then, the pipe is marked according to the size required based on the WO and cut it according to the markings.
3. Setting & Checking: Arranging the pipe according to the specified size and determining the welding points. Then, recheck the dimensions and conformity of the pipe with the working drawings to ensure that the final product will be in accordance with the specifications.
4. Welding: Welding at all specified connection points. The welding process must be carried out carefully to ensure good joint strength and welding quality in accordance with applicable standards.
5. Finishing, Packing, Weighing & Labeling: The finishing stage includes cleaning of welding residue (scale), coating wire mesh sheets using electroplating, recording product weight, and labeling products to be handed over for shipping.

The possibility of defect creation in the production process are drawing-marking-cutting process, welding process, and finishing process

Critical-to-Quality (CTQ) Determination

CTQ are critical characteristics that a product must have because it is directly related to customer needs and satisfaction. The characteristics of a product determine the quality of the quality of the product produced. Thus, CTQ identification has an important role in becoming a benchmark or standard that the company has for a product ready to be handled to the customer. If a product cannot meet the CTQ characteristics, then the product has failed to meet the needs of the customer and can be said to be a defective product.

Based on CTQ determined by company standards, the types of defects that can be found in the production process can be seen in Table 5 below.

Table 3 Defect Types And Ctqs

No.	Defect types	CTQ
1	Shear	Both ends of each panel stick together.
2	Short	Wire stretches straight and does not collide.
3	Penetration	Weld does not break before reaching minimum tension
4	Visual	The entire product layer is coated with a silver color

Based on Table 5 above, there are four CTQ characteristics that standardize a product to be defective or not. Each CTQ is explained as follows.

1. Both Ends of Each Panel Stick Together: it means that both ends of each panel stick together. Wire mesh products consist of rows of iron panels that cross each other vertically and horizontally. This CTQ requires both ends of each panel to stick to the crossing panel.
2. Wire Stretches Straight and Does Not Collide: it means that the wire stretches straight and does not collide. This CTQ requires the crossing steel panels to form a straight line and align with each other. The horizontal panels must be parallel and stretch straight 180 degrees. This also applies to vertical panels.
3. Weld does not break before reaching minimum tension: the third quality characteristic is to prove that the weld does not break before reaching the minimum stress. The stress tests carried out are the tensile strength test and the yield strength test. The tensile test is a test to determine the tensile strength of a product. The test sample will be given a maximum load until the test sample is cut off.
4. The entire product layer is coated with a silver color: The last quality characteristic is silver-colored products. The perfect coating of the product using zinc liquid is characterized by the coverage of the entire wire panel layer with silver color. If it is found that there are areas of the panel that are still visible basic colors that tend to be black or dark-colored, then the product is said to be defective.

Measure Phase

The following data will be used as input for calculating the percentage of defect types on existing conditions, calculating control charts, and calculating DPMO and Sigma Level

Table 4 Total Defects In The Production Process

Period	Total output (unit)	Total defective (unit)
1	19,728	604
2	14,019	420
3	9,557	318
4	14,733	433
5	6,908	196
6	4,415	130
Total	**69,360**	**2,101**

Process Chart

Process chart calculations aim to determine that the collected data comes from production that is under control (in control). The control charts that will be created are p-Chart and u-Chart. The two charts were chosen because the available data is attribute data that can be calculated, and the amount of output produced varies in each period. Control p-Chart is used to calculate the percentage or proportion of defective.

Meanwhile, control u-Chart is used to calculate the percentage or proportion of defects per unit.

1. Calculation of p-Chart (in Example of the 1st Period)

$$\text{CL} = \bar{p} = \frac{\sum pi}{k}$$

$$\text{UCL} = \bar{p} + 3\,x\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$$

$$\text{LCL} = \bar{p} - 3\,x\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$$

$$CL = \bar{p} = \frac{2{,}101}{69{,}360} = 0.0315$$

$$UCL = 0.0315 + 3\ x\sqrt{\frac{0.0315\ x\ (1 - 0.0315)}{19{,}728}} = 0.0352$$

$$LCL = 0.0315 - 3\ x\sqrt{\frac{0.0315\ x\ (1 - 0.0315)}{19{,}728}} = 0.0277$$

Table 7 Calculation Of The Revised Production Process P-Control Map

Period	Total output (unit)	Total defective (unit)	Defective percentage	CL	UCL	LCL
1	19,728	604	0.0306	0.0315	0.0352	0.0277
2	14,019	420	0.0300	0.0315	0.0359	0.0271
3	9,557	318	0.0333	0.0315	0.0368	0.0261
4	14,733	433	0.0294	0.0315	0.0358	0.0272
5	6,908	196	0.0284	0.0315	0.0378	0.0252
6	4,415	130	0.0294	0.0315	0.0394	0.0236
Total	69,360	2,101				

2. Calculation of u-Chart (in Example of the 5th Period)

$$CL = \bar{u} = \frac{\sum ci}{\sum ni}$$

$$UCL = \bar{u} + 3\ x\sqrt{\frac{\bar{u}}{ni}}$$

$$LCL = \bar{u} - 3\ x\sqrt{\frac{\bar{u}}{ni}}$$

$$CL = \bar{u} = \frac{2{,}101}{69{,}360} = 0.0315$$

$$UCL = 0.0315 + 3\ x\sqrt{\frac{0.0315}{6{,}908}} = 0.0379$$

$$LCL = 0.0315 - 3\ x\sqrt{\frac{0.0315}{6{,}908}} = 0.0251$$

Table 8 Calculation of the Revised Production Process u-Control Map

Period	Total output (unit)	Total defective (unit)	Defective percentage	CL	UCL	LCL
1	19,728	604	0.0306	0.0315	0.0353	0.0277
2	14,019	420	0.0300	0.0315	0.0360	0.0270
3	9,557	318	0.0333	0.0315	0.0369	0.0260
4	14,733	433	0.0294	0.0315	0.0359	0.0271
5	6,908	196	0.0284	0.0315	0.0379	0.0251
6	4,415	130	0.0294	0.0315	0.0395	0.0235
Total	69,360	2,101				

This indicates that the data obtained in the production process comes from a controlled process. Hence, the data are valid to be proceeded to the next stage of analysis.

DPMO And Sigma Level Of Existing Process

Both DPMO and Sigma Level are performance measurement parameters of Six Sigma that are calculated to determine the existing performance of production processes. The DPMO and Sigma Level calculations of the production process use data from the number of outputs produced (units) and the number of defects units shown in Table 8 with a production process has the potential to produce four (4) types of defects as shown in Table 5. The calculations can be seen as follows.

$$\text{DPMO} = \frac{\textit{Number of defects}}{\textit{Number of opportunities x Nimber of units}} \times 1{,}000{,}000$$

$$\text{DPMO} = \frac{2{,}101}{69{,}360 \times 4} \times 1{,}000{,}000$$

$$\text{DPMO} = 7{,}573$$

$$\text{Sigma Level} = NORMSINV(1 - \frac{7{,}573}{1{,}000{,}000}) \times 1.5$$

$$\text{Sigma Level} = 3.92888$$

In conclusion, the performance of the existing production process for WWM products at PT HBU produces 7,573 defective units in every one million units produced. The Sigma Level value in the existing production process is 3.92888 from the maximum Sigma Level of 6-Sigma. Therefore, potential improvement efforts are still valid to be performed.

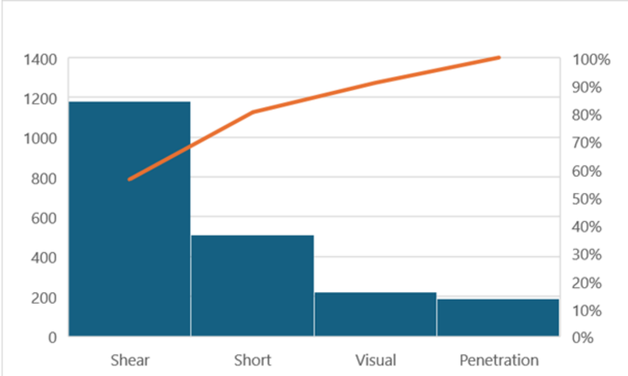
Pareto Chart

Pareto Charts are used to prioritize a problem based on the identification of defect types that have the greatest proportion of influence. The prioritized types of defects will be determined to proceed to the next stage. Prioritization is based on a cumulative percentage of 80%. The result of the cumulative percentage can be seen in Table 9 below.

Table 9 Cumulative Defect Percentage Result Of Production Process

No.	Defect type	Defect quantity (unit)	Defect percentage	Cumulative defect percentage
1	Shear	1,178	0.5607	**0.5607**
2	Short	510	0.2427	**0.8034**
3	Visual	223	0.1061	**0.9096**
4	Penetration	190	0.0904	**1.0000**
	Total	**2,101**		

Figure 1 Cumulative Defect Percentage Result Of Production Process



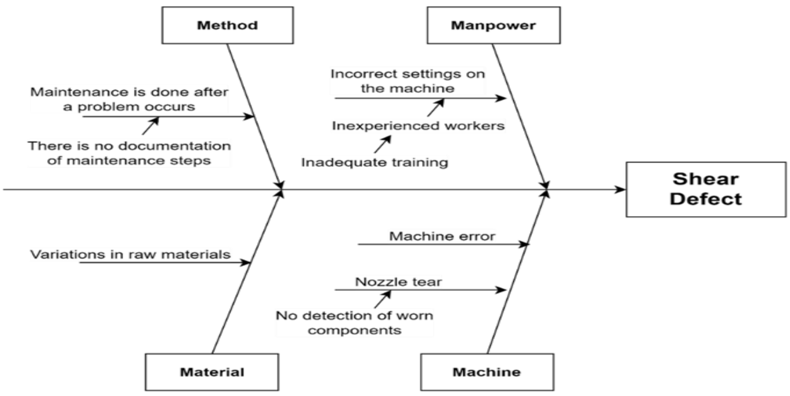
In conclusion, the performance of the existing production process for WWM products at PT HBU produces 7,573 defective units in every one million units produced. The Sigma Level value in the existing production process is 3.92888 from the maximum Sigma Level of 6-Sigma. Therefore, potential improvement efforts are still valid to be performed.From Figure 1, the type of defect that reaches 80% in cumulative defect percentage is shear and short defect, with a cumulative percentage of 80.34%. The shear and short defect types are the two problems that should be prioritized to be addressed by PT HBU. Therefore, only these two defects will be subjected to further root cause analysis in the next stage.

Analyze Phase

Cause-and-Effect Analysis

The interview method used to collect all the potential root causes information for this analysis. This study uses Cause-and-Effect Diagram or Fishbone Diagram to identify the root cause of the problem. The two types of defects that were selected in the previous phase are *shear* and *short*. Therefore, the fishbone diagram was made only to find the root cause of these two types of defects.

Figure 2 Cause-And-Effect Diagram Of Shear Defect



Improve Phase

This study uses Failure Mode and Effect Analysis (FMEA) to determine the priority of improvements to be made. In this case, the Failure Modes will be the potential root causes, and the Failure Effect will be the shear defect and short defect. Furthermore, all identified root causes will be assessed by the manufacturing manager, the quality control supervisor, the quality control staff, and the maintenance supervisor. The scale used in this assessment is the Likert scale from 1-5.

Table 10 The Scale And Parameter For FMEA Assessment

Severity level		Occurrence level		Detectability level	
Likert	Parameters	Likert	Parameters	Likert	Parameters
1	Minor	1	Very rare	1	Very easy
2	Low	2	Rare	2	Easy
3	Moderate	3	Moderate	3	Moderate
4	High	4	Frequent	4	Hard
5	Critical	5	Very often	5	Very hard

This scale determines the parameters used for each of the different S, O, and D criteria. For the Severity criterion, higher scores indicate more severe consequences. For the Occurrence criterion, a higher score indicates more frequent occurrence. For the Detectability criterion, a lower score indicates better detection. Risk Priority Number (RPN) value determines the priority of solving the root cause. RPN is generated from multiplying the severity value, occurrence value, and detectability value of each failure mode (root cause). The higher the RPN value indicates the greater the impact and potential occurrence of problems that can be generated in the production process. Therefore, it is strongly recommended for the issue be the top priority for the company to conduct the proposed improvement given for preventive action

Table 11 FMEA Assessment Result

No	Potential Mode of Failure	Potential Effect of Failure	S	O	D	RPN	Proposed Improvements
1	Machine error	Shear Defect	3.5	3.3	2.8	**31.3**	Create maintenance reporting flow chart and create maintenance SOP for welding and cutting machines
2	No detection of worn components	Shear Defect	3.5	3.3	2.3	**25.6**	
3	There is no documentation of maintenance steps	Shear Defect	3.0	2.3	2.8	**18.6**	
4	Variations in raw materials	Shear Defect	2.8	2.8	2.3	**17.0**	Improve raw material inspection
5	Inadequate training	Shear Defect	3.5	2.8	2.5	**24.1**	Create a process map of internal training program and create the training SOP handbook to train new employees
6	Inadequate training	Short Defect	3.5	2.8	2.5	**24.1**	
7	Limited machine capability	Short Defect	2.8	3.0	2.5	**20.6**	Create a new flow chart to cutting inspection
8	Cutting inspection method not thorough	Short Defect	2.8	2.8	2.3	**17.0**	

This shows RPN value from an average of each S, O, and D values. These results and proposed improvements have been justified to the management, which results in the high risk of failure mode with an RPN value of 31.3.

DISCUSSION

In the previous stage, the priority order of problems that have a large to small impact on the product quality of the production process is recognized. Of all the potential modes of failure that produce potential effects, the proposed improvements designed to address the failure modes are further explained as follows.

1. Flow Chart of Improved Maintenance Reporting and Maintenance SOP for Cutting and Welding Machines: This proposed improvement aims to increase machine reliability by ensuring that maintenance is carried out in a well-planned and documented manner. This flow chart clearly defines the steps to be taken by operators in filling out and reporting maintenance form checklists. With layered supervision and a structured validation process, the responsibility of every individual in the maintenance process becomes more accountable so that operators can no longer fill out checklist forms carelessly. This ensures that all issues are dealt with in a more proactive manner, rather than reactively. Therefore, reducing the amount of downtime by improving the reporting quality of maintenance can prevent undetected machine damage in the future.
2. Flow Chart of Improved Cutting Inspection: This proposed improvement aims to increase the scope of inspection by adding a double-checking inspection method. By tightening the role of manual inspections, the risk of human error, which is usually caused by fatigue, boredom, or unfocused can be minimized by other inspection personnel. Ensuring all wire panels meet the length specifications after the cutting process and before proceeding to the welding process is a way that can be used immediately because it does not require any initial cost. The trade-off is the increase in work lots that need to be filled by inspection operator.
3. Process Map of New Employees Training Program and Training SOP Handbook: This proposed improvement aims to enhance the competencies of new operators or employees by providing structured and in-depth training journey that meets operational needs. The process map provides a clear flow on how new employee training should be carried out, from initial orientation to specific technical training related to machines and production processes. The benefit is that each employee receives the knowledge needed in accordance with company standards from the start. This results in new employees will more quickly adapt to the work environment which reduces the time required to achieve full productivity.
4. Flow Chart of Improved Raw Material Inspection: This proposed improvement aims to tighten the existing quality control by adding a sampling test phase performed by the production department to test if the material complies with the standard before it can proceed to a large-scale production. After the sampling test is conducted by the production department, the results are returned to QC for final assessment. If the test results show that the material complies with the standard, then the material can proceed to mass production. If not, the raw material is returned to the supplier for replacement. This feedback loop provides dual control to ensure that only materials that are materials that are up to the standard (not only written on material certificate) are used in production. By being able to identify the potential material problems at an early stage, the company could prevent any major problems in the large-scale production process.

CONCLUSION

This research focuses on analyzing product defects in the production process of welded wire mesh at PT HBU. The main objective of this research is to identify the main causes of product defects, propose effective improvements, and develop an implementation plan for these improvements. The main causes of product defects at PT HBU are operators' inconsistency to detect post-production defects, insufficient training and certification of machine workers, and insufficient supervision on scheduled machine maintenance. Some of the main types of defects found include wire shearing or not perfectly straight (shear defect) from welding machines and wire that is not long enough to attach to another wire (short defect) from cutting machines.

Also, this study proposes some improvement proposals that are expected to reduce or even eliminate the defects. These proposals are designed based on the findings of the analysis and are packaged in the form of actions that can be practically implemented. There are:

1. Flow Chart of Improved Maintenance Reporting and Maintenance SOP for Cutting and Welding Machines.
2. Flow Chart to Improve Cutting Inspection.
3. Process Map of New Employees Training Program and Training SOP Handbook.
4. Flow Chart of Improved Raw Material Inspection.

The implementation plan for the proposed improvements, first, the development and implementation of improved maintenance reporting flows and standard operating procedures (SOPs) for cutting and welding machines will be implemented within 45 days. This process includes initial trials to identify inefficiencies that will be overseen by the Maintenance Supervisor, refinement and testing of the flow and SOPs in a real operational environment that will involve the Manufacturing Manager, Maintenance Supervisor, and Production Supervisor, and implementation of the refined flow under the supervision of the Production Supervisor. Collaboration with the maintenance team will also be conducted to ensure the accuracy and applicability of the new flow, led by the Manufacturing Manager and Maintenance Supervisor. Second, improvements to the cutting inspection flow will be made within 35 days, starting with the implementation of the proposed process to identify inefficiencies by the Production Supervisor and QC Supervisor. This step is followed by data collection and review by the QC Supervisor to identify defects, before finally refinement and validation through a pilot test led by the Production Supervisor and QC Supervisor.

Third, the development of a process map for the new employee training program and the preparation of a training SOP guidebook will be completed within 60 days. This process includes an initial pilot test to assess the effectiveness of the proposed training flow, review and identification of weaknesses by Manufacturing Managers and Human Resource Department (HRD), and reassessment of training needs in various departments. Thereafter, the enhanced process map will be documented in the Training Handbook by Manufacturing Managers and HRD. Last, the development of an improved raw material inspection flow will be implemented within 30 days, with the implementation of the proposed inspection flow and monitoring of its effectiveness by the QC Supervisor, followed by a review and refinement of the process to reduce the risk of raw material shortages.

SUGGESTION

For further research, it is recommended that this research be continued by developing predictive models or analytics that can be used to monitor and predict potential product defects in real-time. Technologies such as Internet of Things (IoT) and big data analytics can be the focus of further research to improve the effectiveness of the production system and product quality.

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