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Efforts To Improve the Quality of Welding Plastic Pallet Type HDX1210R With Six Sigma Method at PT. Pallets

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ABSTRACT

PT. Pallets is a manufacturing company that processes plastic waste into products that have value, namely plastic pallets. A plastic pallet is a flat city-shaped container used as a base for storing and transporting goods in logistics warehousing. This study aims to improve the quality of plastic pallet welding products of the HDX1210R type at PT. Pallets. This study uses the Six Sigma method with the DMAIC (Define - Measure - Analyze - Improve - Control) approach with the help of fishbone diagrams, Pareto diagrams, and FMEA. From the company's historical data from March 2022 to March 2023, 3 types of defects were obtained, with loose welding as the highest type of defect, with a percentage of 89% of the total product defects. The overall DPMO average value is 49908.1405, and the average sigma value is 3.191. From FMEA calculations, the highest RPN value is obtained for frequently changing over machines with a scale value of 480. The proposed improvements can be made by changing the hitter model and size, modifying the mold (pallet molding) by adding the welding area on the pallet and making SOPs for producing HDX1210R-type pallet welding.

Keywords: *Pallet, Quality, Six Sigma, DMAIC, FMEA*

Introduction

Product quality is one of the cores of a marketing activity because the product is the result of one of the company's activities or activities that aim to be offered to the target market to meet the needs and desires of its consumers. Basically, in buying a product, a consumer does not only buy the product but also the benefits or advantages that can be obtained from the product he buys. Therefore, a product must have advantages over other products, one of which is the product's quality. Product quality is one of the keys to competition among business actors offered to consumers.

A product can be offered to a market to satisfy a want or need, including physical goods, services, experiences, events, people, places, properties, organizations, information, and ideas[1].

PT. Pallets is a manufacturing company that processes plastic waste (recycling) into a valuable product, namely plastic pallets. A plastic pallet is an important piece of equipment, or a flat city-shaped container used as the base of an item that is usually used to store and transport goods in the logistics warehousing industry. Various pallet products are produced at this company, but this research is focused on the HDX1210R type pallet. The HDX1210R type pallet is a new product at PT. Pallets will start production in March 2022. The number of requests for production of the HDX1210R pallet type +/- is 3500 pallets per month, but in the production of these pallets, many product waste defects still occur.

The problem faced by PT. Pallets are a waste of defective products where the products' quality is not following what consumers want, such as cracked pallet products, less strong welding results, and non-uniform pallet dimensions. Therefore, PT. Pallets need to improve product quality. The cause of the defective waste occurs in the pallet welding process. The types of defects that occur in the pallet welding process are classified into three types of defects: cracks, dimensions of the results of the pallet after welding are not the same, and the results of the welding are less strong (loose).

Waste can be interpreted as all activities carried out in processes that do not provide added value in the process from input to output. Generally, there are seven kinds of waste in the production system mentioned by Taichi Ono, a Toyota executive, who was the first to initiate the seven kinds of waste [2].

A defect is a product that does not meet specifications, causing rework, scrap, production delays, the need for investigations, etc. Imperfections or discrepancies can cause this waste during production [3].

This study uses a Six Sigma approach. Six Sigma is a method that aims to reduce variation and improve process control. This system is comprehensive and flexible to achieve, maintain, and support what needs to be done and use which methods are needed and the data needed. Six Sigma has five cycles of DMAIC (Define, Measure, Analyze, Improve, and Control) phases, a continuous improvement process toward the Six Sigma target. The purpose of DMAIC is to find the point where the problem is, identify the cause of the problem, and finally find a solution to improve a product [4]. Six Sigma uses statistical tools to reduce process variations which can ultimately reduce production costs without affecting quality[5].

Six Sigma is a well-structured methodology that helps organizations achieve their goals because of its role as a problem-solving technique. This study discusses the application of the Six Sigma methodology to the household appliance industry in Egypt. This paper follows the Six Sigma DMAIC methodology to systematically identify and determine the root causes of these defects and provide reliable solutions to reduce/eliminate them[6].

Discuss how to reduce defects at the PT Sharp Electronics Indonesia television factory. PT Sharp Electronics Indonesia is one of the companies that produce televisions, especially Light Emitting Diode (LED) TVs, which often experience quality problems; however, there are still many defects that occur in the production process. This study aims to reduce the number of defects in the television factory PT Sharp Electronics Indonesia by using the Six Sigma method through the Define, Measure, Analyze, Improve, and Control (DMAIC) stages. This quality improvement is simulated using a Monte Carlo simulation divided into three successful solution scenarios (reducing the number of defects of the no raster, no picture, and no power types). The Cpk value in the simulation results has increased to 1.1 each, 1.11, and 1.12[7].

Discusses the process capability based on defects using the Six Sigma DMAIC method approach, then find out the proposed implementation of quality control by analyzing the causes of defects in the chair production process, namely by seeking continuous improvement with the 5W + 1H concept, at the define stage will determine the research object that has the highest defect rate based on the voice of the customer (VOC). Sigma. In the analysis phase, we will analyze CTQ with a Pareto Diagram to analyze the source of the problem with a fishbone diagram. In the improvement stage, make suggestions for improvements using the 5W+1H method[8]. Discussing quality control is an important thing that a company must do to reduce or minimize defective products. Companies can analyze defects in a product by using one of the quality control methods, namely Six Sigma, to improve quality by promoting the concept that there will only be 3.4 product defects for every 1 million products produced[9].

Quality is a standard characteristic of a product (goods or services) that aims to satisfy customers. Good quality has goals and benefits that go hand in hand. Producers will gain consumers' trust and have good business relationships by providing guaranteed quality for consumers. Therefore the role of quality is very important for products (goods or services) to be able to compete effectively with competitors and to be able to understand customer satisfaction more deeply and understand concepts for improving the quality of products (goods or services) produced[10].

Products are classified into 2, including the following: Product Classification Based on Durability and Product Classification Based on Its Use[11]. Quality control is an activity that is closely related to the production process, where this activity is carried out by examining and testing product quality characteristics to assess the ability of the production process associated with product specification standards by conducting further analysis of the results of tests and inspections carried out to find the causes of deviations to take then preventive and corrective steps. Quality control aims to produce quality products that can compete in the market and are acceptable to society[12].

Six Sigma is a quantity that can be translated as a measurement process using tools and techniques to reduce defects to no more than 3.4 DPMO (Defects per Million Opportunities) or 99.99% focused on achieving customer satisfaction[13].

Six aspects need to be considered when applying the Six Sigma concept, namely: Identifying the characteristics of a product that can satisfy customers in terms of what is needed and according to customer expectations, Classifying all characteristics of quality as CTQ (Critical To Quality), Determining whether each CTQ can be controlled through control of materials, machines and work processes, Determining the maximum tolerance limit for each CTQ according to what the customer wants, Determining the maximum process variation for each CTQ, Changing product and process designs in such a way as to be able to achieve the six s value target sigma[14].

DMAIC is an approach to solving data-based problems that can help improve and optimize products, designs, and business processes. DMAIC has five stages: Define, Measure, Analyze, Improve, and Control[15].

Failure Mode and Effect Analysis (FMEA) is a methodology used to identify, classify, and analyze potential risks in a defective product. Originally discovered in 1949, in 1956, Boeing developed it, taken up by the automotive industry, and adapted it to be a tool for improving the quality of products produced. This FMEA method is carried out to analyze the occurrence of failed products, and failure can be defined according to the final impact related to the success of a system's mission. The FMEA process is used to identify and prioritize repairs to the types of potential failures that have occurred. To determine these priorities, a weighting of values is carried out in the form of a scale for each type of defect based on Severity (fatality rate), occurrence

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(frequency level), and Detection (detection level). After that, determine the RPN (Risk Priority Number) value which is the final result of multiplying Severity, Occurrence, and Detection[16].

Research Methods

This research uses the Six Sigma method with the research flow using DMAIC (Define, Measure, Analyze, Improve, and Control). DMAIC is a process of improvement towards the Six Sigma target, which aims to find the point where the problem is, identify the cause of the problem, and finally find a solution to improve a product. The flow of this research can be seen in the following figure.

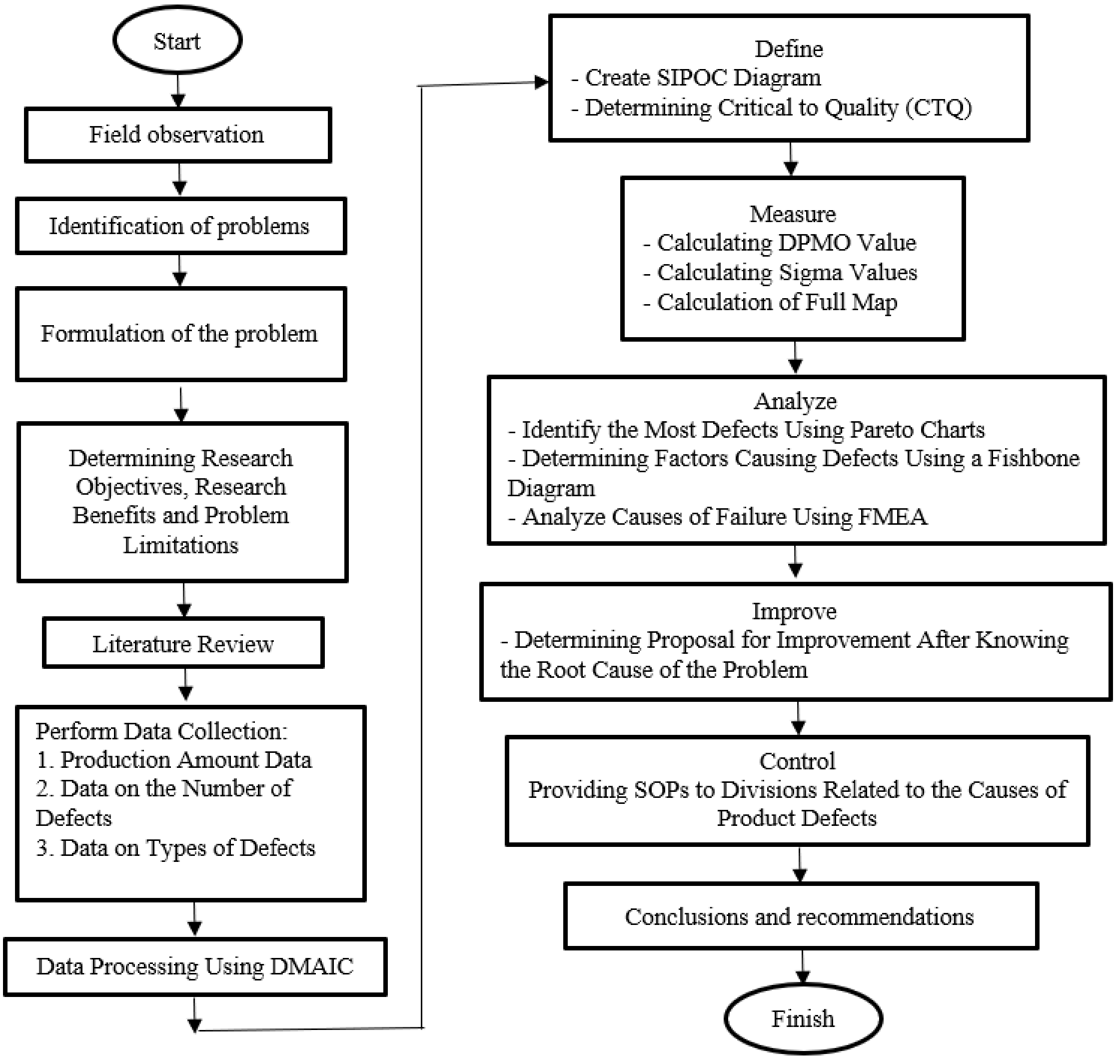

Figure 1. Research Flow

Results and Discussion

Data collection

The data collection results, carried out by looking at the March 2022 – March 2023 production reports, obtained three types of attribute defects: loose welding, oblique welding, and cracked pallets that occur in the HDX1210R type plastic pallet welding process. The production report data can be seen in Table 1.

Table 1. Data on Production and Attribute Defects for March 2022 - March 2023

Month	Total Production (Unit)	Total Disabilities (Unit)	Disability percentage (%)
arch	2890	580	20,07%
April	3005	597	19,87%
May	3116	697	22,37%
June	3578	860	24,04%
July	3265	715	21,90%
August	3185	580	18,21%
September	3378	653	19,33%
October	3403	415	12,20%
November	3615	315	8,71%
December	3505	299	8,53%
January	3580	263	7,35%
February	3603	224	6,22%
March	3670	215	5,86%
Total	43793	6413	194,64%
Average	3369	493	14,97%

Data processing

At this data processing stage, it is carried out using the DMAIC (Define-Measure-Analyze-Improv-Control) method with a Six Sigma approach. The DMAIC method is used as a stage for solving problems in the company. The following stages of DMAIC are as follows:

a. Stage *Define*

At the definition, the stage is done to identify the main problem to be solved. At this stage, it will be explained as a SIPOC diagram and the definition of critical to quality (CTQ).

b. Stage *Measure*

At the measuring stage, calculations are carried out to determine the value of Defects Per Million Opportunities (DPMO), sigma level, and control chart.

DPMO Value Calculation

Defect Per Million Opportunities (DPMO) is a measure of a failure in Six Sigma, which can show failure per million opportunities. The formula used to get the DPMO value is as follows:

$$\text{DPMO} = \frac{Number\ of\ defective\ products}{Number\ of\ products\ inspected\ x\ CTQ\ potensial} \text{ x } 1000000$$

Table 2. Recapitulation of DPMO Values in March 2022 - March 2023

Month	Total Production (Unit)	Total Disabilities (Unit)	CTQ	DPMO
March	2.890	580	3	66897,3472
April	3.005	597	3	66222,9617
May	3.116	697	3	74561,4035
June	3.578	860	3	80119,2473
July	3.265	715	3	72996,4267
August	3.185	580	3	60701,2036
September	3.378	653	3	64436,5502
October	3.403	415	3	40650,4065
November	3.615	315	3	29045,6432
December	3.505	299	3	28435,5682
January	3.580	263	3	24487,8957
February	3.603	224	3	20723,4712
March	3.670	215	3	19527,7021
Total	43.793	6413		648805,827
Average	3.369	493		49908,1405

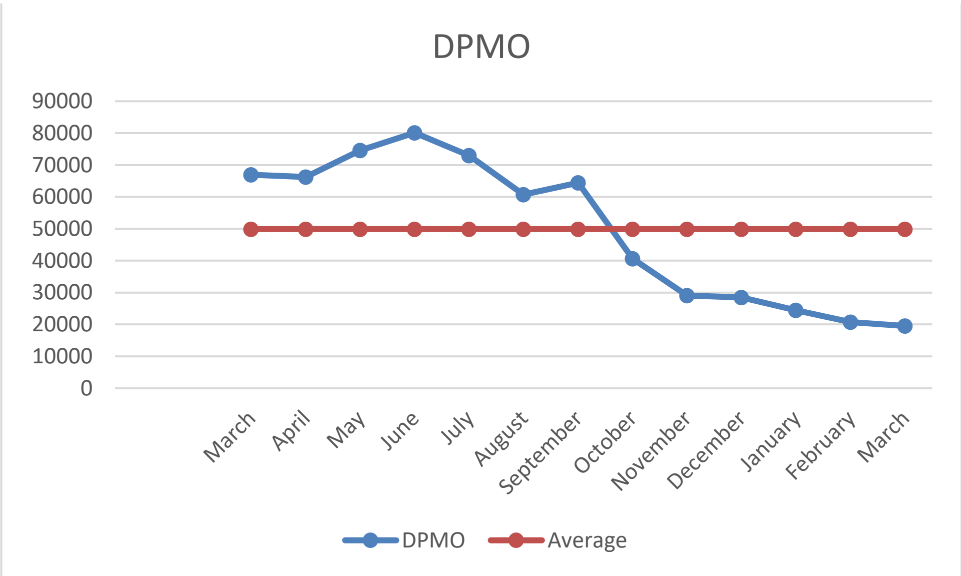

Figure 2. Recapitulation of DPMO Values in March 2022 - March 2023

Calculation of Sigma Value

After obtaining the DPMO value, a conversion is carried out to get the Sigma value, with the help of the MS. Excel software using the following formula:

$$\text{Sigma value} = \text{NORMSINV}\left(1 - \frac{DPMO}{10^6}\right) + 1{,}5$$

Table 3. Sigma Value Data in March 2022 - March 2023

Month	DPMO	Nilai Sigma
March	66897,34717	2,999304350
April	66222,96173	3,004526235
May	74561,40351	2,942636815
June	80119,24725	2,904269898
July	72996,42675	2,953832129
August	60701,20356	3,048913950
September	64436,55023	3,018560737
October	40650,40650	3,243187816
November	29045,64315	3,395008419
December	28435,56824	3,404299906
January	24487,89572	3,468802358
February	20723,47118	3,539030914
March	19527,70209	3,563602671
Total	648805,8271	41,4859762
Average	49908,14054	3,191228938

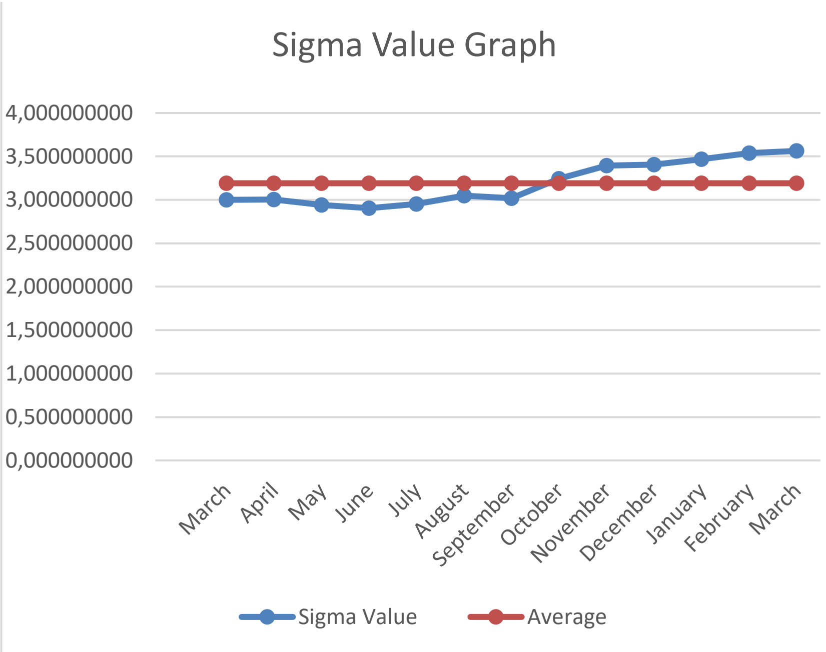

Figure 3. Sigma Value Data in March 2022 - March 2023

Calculation of Control Map
A control chart is a tool that is made using a statistical method to analyze the possibility of whether there are deviations from an output that has been produced, where the data used will be interpreted to become a control chart.
The average proportion of total disability is:

$$P = \frac{\sum np_1}{n_1} = \frac{580}{2.890} = 0,20069$$

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The calculation of the lower control limit of LCL and upper control limit of UCL for subgroup 1 is as follows:

$$\overline{P} = \frac{\sum np}{\sum n} = \frac{6413}{43.793} = 0{,}14644$$

$$LCL = \overline{P} - 3\,\frac{\sqrt{P(1-P)}}{n_1} = 0{,}14644 - 3\,\frac{\sqrt{0{,}20069\,(1-0{,}20069)}}{2.890} = 0{,}16617$$

$$UCL = \overline{P} + 3\,\frac{\sqrt{P(1-P)}}{n_1} = 0{,}14644 + 3\,\frac{\sqrt{0{,}20069\,(1-0{,}20069)}}{2.890} = \quad 0{,}12671$$

Based on the calculation of the LCL and UCL values above, it can be seen that the proportion of disability (p) in subgroup 1 is still within control limits. The calculation of control limits on other subgroups can be seen in the following table.

Table 4. Results of Calculation of Control Limits in March 2022 - March 2023

Month	Total Production (Unit)	Total Disabilities (Unit)	The proportion of Defective Products	UCL	CL	LCL
March	2.890	580	0,20069	0,16617	0,14644	0,12671
April	3.005	597	0,19867	0,16579	0,14644	0,12709
May	3.116	697	0,22368	0,16544	0,14644	0,12744
June	3.578	860	0,24036	0,16417	0,14644	0,12871
July	3.265	715	0,21899	0,16500	0,14644	0,12788
August	3.185	580	0,18210	0,16523	0,14644	0,12765
September	3.378	653	0,19331	0,16469	0,14644	0,12819
October	3.403	415	0,12195	0,16462	0,14644	0,12826
November	3.615	315	0,08714	0,16408	0,14644	0,12880
December	3.505	299	0,08531	0,16435	0,14644	0,12852
January	3.580	263	0,07346	0,16417	0,14644	0,12871
February	3.603	224	0,06217	0,16411	0,14644	0,12877
March	3.670	215	0,05858	0,16395	0,14644	0,12893
Total	43.793	6413	1,94642			
Average	3.369	493	0,14972			

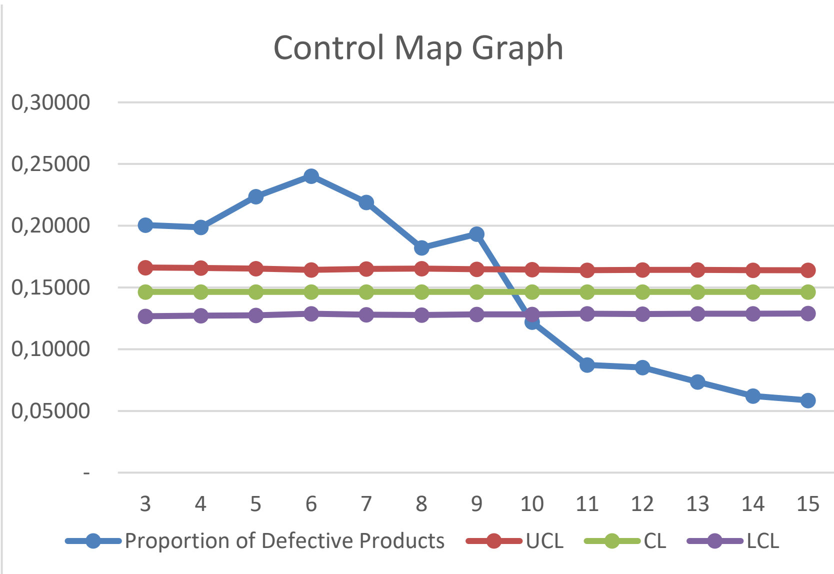

Figure 4. Results of Calculation of Control Limits in March 2022 - March 2023

c. **Stage *Analyse***

In this analysis phase, identify the source and root cause of the defective product. An analysis was carried out using a Pareto chart to determine the priority for improvement in the types of defects and a fishbone diagram to get the root causes of problems that occur in producing HDX 1210 R pallets in the welding machine section.

Pareto Charts

Table 5. Pareto Chart Data for Defect Products in March 2022 - March 2023

Defects Type	Defects Frequency	Percentage Frequency of defects	Cumulative Percentage Frequency of Defects
Loose Welding	5708	89%	89%
Welding Oblique	601	9%	98%
Cracked	104	2%	100%
Total	6413	100%	

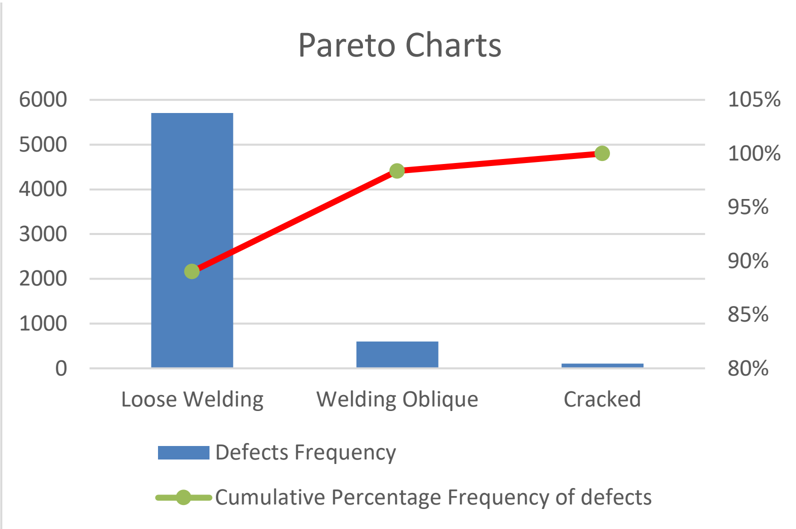

Figure 5. Graph of Pareto Chart Data for Defect Products in March 2022 - March 2023

Fishbone Diagrams

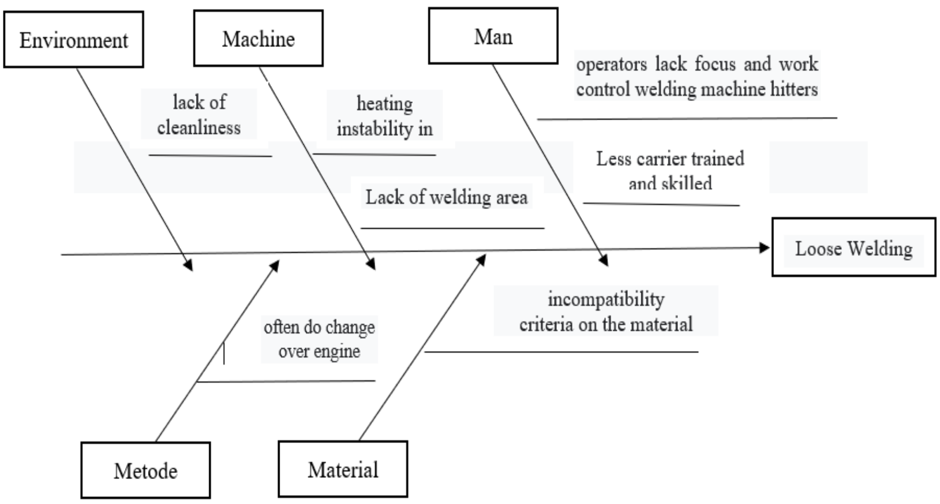

Figure 6. Fishbone Diagram

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FMEA (*Failure Mode & Effect Analysis*)

Table 6. Calculation Results from FMEA

Failure Modes	Potential Failure	*Severity*	*Occurrence*	*Detection*	RPN
Loose Welding	Man:				
	* Operators lack focus and work control	4	4	4	64
	* Operators are less trained and skilled	5	4	5	100
	Environment:				
	* Lack of maintaining cleanliness	6	4	6	144
	Method:				
	* Often done change over a machine	10	8	6	480
	Machine:				
	* Heating instability on welding machine hitters	10	7	5	350
	* Lack of welding area	7	7	5	245
	Material:				
	* Non-compliance with the criteria for the material	2	4	3	24

From the results of the FMEA calculation above, it can be concluded that the potential for loose welding products can be seen from the highest RPN value located in the method of frequently changing over machines with a scale value of 480, then followed by heating instability on the welding machine hitter with a scale value of 350, and the lowest RPN value is in the material, namely the non-conformity of the criteria for the material with a scale value of 24.

d. Stage *Improve*

This stage contains suggestions for improvements the company can make to produce optimally. The proposed improvement is obtained from an analysis using the fishbone diagram that has been made.

1. Man

Reason:

a) Operators lack focus and work control.

b) Operators are less trained and skilled.

Proposed Improvements:

a) The company establishes rules that must be obeyed by all employees at work. For example, it is forbidden to talk or chat during working hours.

b) It is necessary to hold training as often as possible for all operators to be more trained and skilled in operating the machine.

2. Environment

Reason: lack of cleanliness

Proposed Improvements:

The 5S method is a proposed improvement to increase the convenience of processes, products, and workplaces by involving operators who work during the production process. The 5S method is the basis for continuous improvement (kaizen), which consists of a series of activities to eliminate waste that causes errors, defects, and workplace accidents.

3. Machine and Method

Reason:

a) Heating instability on the welding machine hitter
b) Often do change over a machine.
c) Lack of welding area

Proposed Improvements:

a) The first proposed improvement to address the causes that occur in points (a) and (b) is to replace the hitter model and size on the welding machine.

Figure 7. Model Hitter Welding Pallet Type HDX1210R Size 1200 x 1000 mm (Before Improve)

Figure 8. Model Hitter Welding Pallet Type HD1107 Size 1100 x 700 mm (Before Improve)

Figure 9. Model Hitter Welding Pallet Type HDX1210R and HD1107 Size 1300 x 1300 mm (After Improvement)

Looking at the hitter model HD 1107 for a stable hitter temperature and minimal loose welding defects, the company finally made improvements to the hitter model HDX 1210 R. After the improvement, there was a change in the size of the hitter to 1300 x 1300 mm. This is also very good in terms of method because there is no need for a changeover hitter when the machine is running with a different product. So, this hitter model is very suitable for use up to a pallet size of 1300 x 1300 mm.

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b) The second proposed improvement made to overcome the causes that occur in point (c) is a modification of the mold (pallet molding) by adding pallet welding areas to the Top and Bottom molding sections or HDX 1210 R pallet-type molding machines.

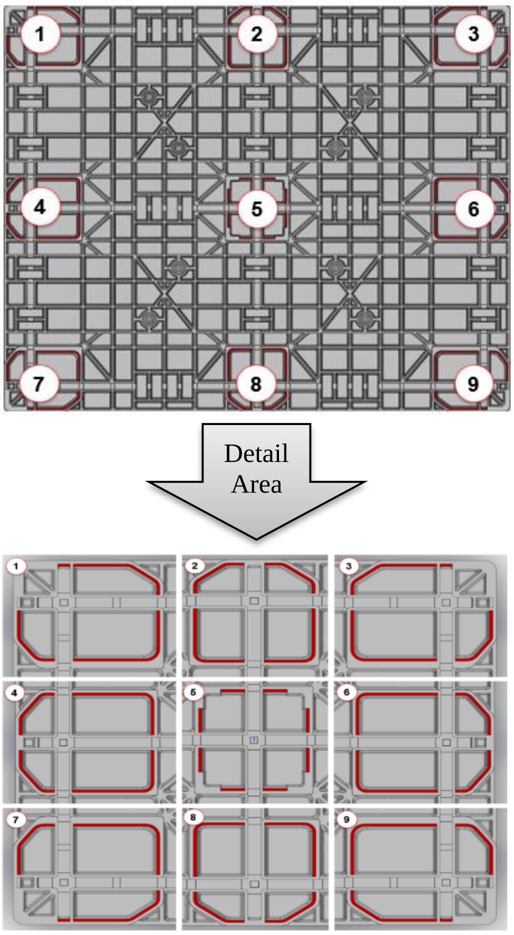

Figure 11. Additional Welding Area on The Top of The HDX1210R

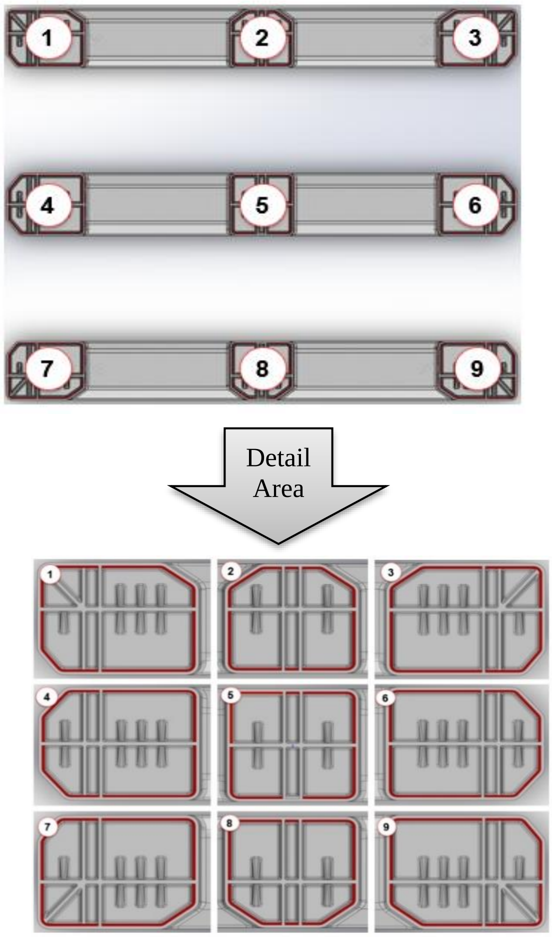

Figure 10. Additional Welding Area on The Bottom of The HDX1210R

Information:
a) Additional thickness of the HDX1210R runner wall to expand the welding area.
b) Additional total welding area of 7-8mm
c) 9 feet on the HDX1210R had wall thickening.

4. Materials

Reason: Non-compliance with the criteria for the material

Proposed Improvements: By making quality standards for material criteria that can be used, these standards can later be submitted to each supplier so that suppliers can also find the material criteria needed.

e. Stage *Control*

This stage is the final analysis of the Six Sigma process, which focuses on the actions and improvements made. The actions and improvements in these controls ensure that the SOP is running properly so that employees understand and understand the standardization of the work being carried out, Recording or recording all defective products every day as material for evaluating future improvements and communicating them to all relevant employees and there is a need for periodic outreach so that all workers continue to implement the proposed improvements that have been implemented, and the proposed improvements must be implemented to minimize defective products that occur in the welding process.

Conclusion

Based on the results and discussion above, it can be concluded that the results of identification and analysis using fishbone diagrams and FMEA calculations, the main factor that greatly influences the occurrence of defects in HDX1210R type plastic pallet welding products is the method of frequent welding machine changes. The main improvement proposed is to change the model and size of the hitter on the welding machine. Pallet type hitter welding model HDX1210R after being upgraded to flat with a size of 1300 x 1300 mm, Modification of the mold (pallet molding) by adding a pallet welding area on the top and bottom molding or HDX1210R pallet type molding machine.

Acknowledge

Companies need to carry out periodic evaluations so that they can anticipate sizeable defects and ensure that SOPs run well so that employees understand and understand relate to the standardization of work carried out, record or record all defective products every day as material for evaluation of future improvements and communicate to all relevant employees. There is a need for regular socialization so that all workers continue to implement proposed improvements that have been implemented, as well as suggestions for improvements to be implemented to minimize defective products that occur in the welding process.

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