

Six Sigma as a Method for Controlling and Improving the Quality of Bed Series Products

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Abstract. *The research was conducted at PT. XYZ where there were defect problems in bed series products so that additional time is needed to repair a product. One way to improve quality in a production process is the Six Sigma method with the stages of DMAIC. The calculated average of DPMO values and Sigma Level results from 58558.56 and 3.07, which is still not acceptable because it is still far from 6 sigmas. After that analyzing the root causes of defect product problems, then the priority problem is carried out using (RPN) where the highest value is at the assembly work station because the material that has been used up in the warehouse has an RPN of 405 so that it becomes a top priority for repairs. With the standardization and documentation, proposed improvements that have been given then the possible defects of Electric Lovina Bed 3 Motor will be reduced.*

Keywords: *Six Sigma; DMAIC; improve; defect.*

I. INTRODUCTION

Quality control can generally be defined as a system for maintaining desired quality levels, through the feedback on the characteristic of a product or service and the implementation of corrective actions, in the case of deviations of such characteristics from the specified standards (Mitra, 2008).

In companies, quality control has long been established as an essential management strategy to achieve a competitive advantage (Alghamdi & Bach, 2013). Six Sigma is one of the latest quality improvement initiatives that has gained popularity and acceptance in many industries worldwide (He & Goh, 2015). It is claimed that the Six Sigma implementation brings more favorable results for the company compared to traditional quality initiatives in terms of changing the quality improvement program (Parast, 2011). Therefore, a good understanding is needed in implementing

Six Sigma in the company to manage the quality of a product.

The quality of a product is a significant determinant of consumer choices for industry products (Rehman et al., 2017). Hence, developing quality products reduces production defects and improves the company's product quality.

Six Sigma is a structured methodology for improving processes that are focused on reducing process variations (process variances) while reducing defects (products/services that are out of specification) by using statistics and problem-solving tools intensively (Pepper & Spedding, 2010). In its application has DMAIC stages namely: define which is the phase of determining the problem, the measure is the phase of measuring the level of disability, analyze is the phase of analyzing the causes of problems in the process, improve is the phase of improving the process and eliminating the causes of defects, and control which is the supervision phase process performance and ensure defects do not appear again (Hernadewita et al., 2019).

Six Sigma can also be used as a measure of industrial system performance that enables companies to make improvements with actual breakthrough strategies and can be seen as controlling customer-focused industrial processes about process capabilities (Chiehyeon et al., 2019). The higher the value of sigma achieved, the industrial system performance will improve. Thus, it is necessary to research analysis of

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improving the quality of defective products to identify the cause of defects and provide recommendations so the company can compete with other competitors (Sachin & Dileepal, 2017).

Various studies have been conducted using Six Sigma to eliminate defects and improve the manufacturing process. In the last decade, it has become an important topic in the industry sector (Hernadewita et al., 2019)

There have been many studies on the implementation of Six Sigma to improve the product quality, such as the implementation of Six Sigma with the Pareto diagram approach to determine the priority for types of defects that shall be repaired. At the same time, the number of defects is the sole parameter being considered (Hernadewita et al. (2019). Meanwhile, Gupta et al. (2018) apply the Six Sigma method to identify risks in the tire industry and use the VOC (Voice of Customer) method based on customer complaints data to prioritize the type of defects.

There has been a study conducted by Mansur et al. (2016) where the Six Sigma and FMEA methods have been applied to reduce defects and waste in bush product production. The study is focused on the type of defects and the FMEA method as a prioritization tool to make improvements based on the highest RPN value, which considers severity, occurrence, and the detection factor.

PT. Mega Andalan Kalasan is a hospital equipment manufacturing company in Indonesia that produces various bed series products, room accessories, and other hospital equipment. The quality problem is often verified at the final inspection phase, especially the bed series products, then it will extend the production process for reparation. Hence, to overcome the problems, the company needs to do quality control in an early phase.

This research was conducted on Electric Lovina Bed 3 Motor PT. Mega Andalan Kalasan and the data used in this study are the defect product data from May 2019 to October 2019. The Six Sigma approach will be applied in this study using the DMAIC method to evaluate and improve the products' quality, then the causes of defective products could be solved. Failure mode and effect

analysis (FMEA) is conducted to obtain the major causes of defective products with risk assessment. This study's result would then be the sequence for reparation, which has more impact on improving the product quality of bed series products. The prioritization focused on the causes of defects at each workstation then the reparation shall be performed at the station level, not at the level of certain types of defects. Therefore, this study is expected to contribute to a deeper understanding of product quality improvement in the industry. Besides, the study cover in the hospital equipment products is still infrequent.

II. RESEARCH METHOD

This research is conducted on rework inspection products and finished products by field observations and collecting data. Field observations were performed from 6 January to 17 January 2020. The purpose of the observations is to study the company's manufacturing process, which covers the business process's general understanding and recent operation conditions. In addition, the discussion with the operator and the head of the unit is also conducted. After collecting the data, the Six Sigma approach with stages of DMAIC (Define, Measure, Analyze, Improve, Control) would be applied to improve quality products. It is noted that it will result in risk assessments and achieve improvements based on predetermined priorities (Noori & Latifi, 2018).

The first stage of Six Sigma is to define the production process, especially in the quality improvement process. At this stage, interviews and observations are performed to determine the production process of bed series product SIPOC (Supplier - Input - Process - Output - Customer) diagram. It is noted that it will perceive the process flow, the sequence of processes and interactions between processes, and the components involved in each cycle (Mishra & Sharma, 2014).

Second, in this measurement stage, defects per million opportunities (DPMO) and Sigma Quality Level are calculated to measure the performance process based on the number of

defects per million opportunities (Girmanová et al., 2017). The following is the calculation with Excel software to evaluate DPMO (Erdoğan & Canatan, 2015) and a sigma level based on the following formula (Hernadewita et al., 2019), namely:

$$DPMO = \frac{\text{Number of defective products} \times 1,000,000}{\text{Number of products} \times \text{Opportunity}} \dots (1)$$

$$\text{Sigma level} = \text{normsinv} \left(\frac{1 - DPMO}{1,000,000} \right) + 1.5 \dots (2)$$

Third is the analysis stage, and a fishbone diagram is applied to identify possible causes for an effect or problem. In contrast, it is derived from the defect product data of bed series products from May 2019 to October 2019.

Fourth, the improvement stage is conducted after the root causes of the problem have been identified. It is noted that it is necessary to take corrective action to improve product quality based on the identified root causes (Smętkowska & Mrugalska, 2018). This study applies Failure Mode and Effect Analysis (FMEA) to explain resource allocation and priorities of the existing

problems to prepare the improvement plan based on the Risk Priority Number (RPN) value resulted from the multiplication results between the incident, the severity, and the detection factor (Suryoputro et al., 2019). This analysis categorizes the type of defect based on the process or station to identify the corrective action correlation. Then it will minimize the cost and create more impact.

Last is the control stage; the procedures and documentation of the quality improvement results must be analyzed for sustainability so the defect will be reduced consistently. Then the ownership or responsibility is transferred from the Six Sigma team, which signifies the Six Sigma project ends at this stage (Amitrano et al., 2015).

III. RESULT AND DISCUSSION

Based on the recapitulation of e rework inspection report data from May 2019 to October 2019 Electric Lovina Bed 3 Motor products, the percentage between total defect and total production during May-October 2019 reach between 12,5% and 63,6%.

Table 1. Quality Data Rework Report for May-October 2019

PRODUCTION DATA								
	No. Catalog	May	Jun	Jul	Aug	Sep	Oct	Total
LOVINA	75005	43	26	16	30	14	11	156
	75005 SO	6	0	0	0	2	0	46
	Total Production	49	26	16	30	16	11	148
	Total Defects	23	10	3	7	2	7	52

Table 2. Quality Data Rework Report based on Group of Defect in May-October 2019

No	Disability Category	Number of Defects	Percentage of Total (%)
1	Functional	25	17.7
2	Completeness of Components	46	32.6
3	Welding/welding	14	9.9
4	Material	14	9.9
5	Painting	7	5.0
6	Appearance / Aesthetics	35	24.8
	Total	141	100.0

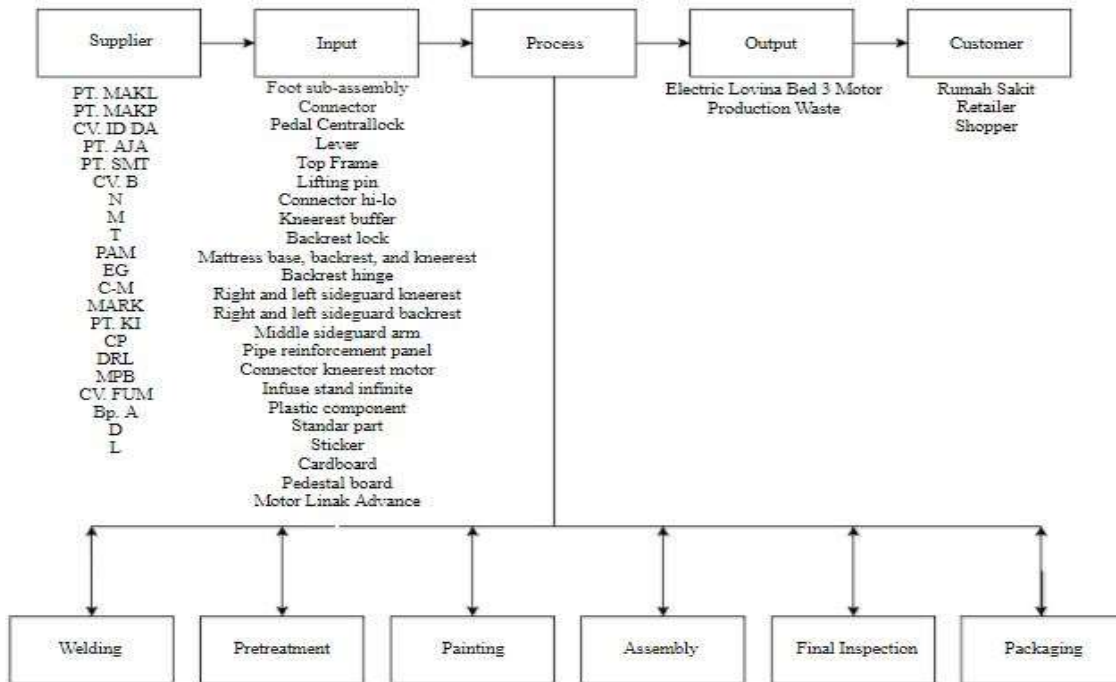


Figure 1. Diagram of SIPOC Electric Lovina Bed 3 Motor

Table 3. Calculation of DPMO and Sigma Values

NO	MONTH	TOTAL DEFECT	TOTAL PRODUCTION	Critical to Quality	DPMO	SIGMA VALUE
1	May	23	49	6	78231.29	2.92
2	June	10	26	6	64102.56	3.02
3	July	3	16	6	31250.00	3.36
4	August	7	30	6	38888.89	3.26
5	September	2	16	6	20833.33	3.54
6	October	7	11	6	106060.61	2.75
AMOUNT		52	148			
PROCESS VALUE				6	58558.56	3.07

Additionally, the defect is categorized into six disability categories: functional, completeness of components, welding, material, painting, and appearance/aesthetics, where the most dominant disability category during the term is the completeness of components, which has a percentage of the total number of defects is about 32.6%. The following is the recapitulation of the rework inspection report data by category of disability in May – October 2019.

Define

At this stage, the SIPOC (Supplier – Input – Process – Output – Customer) is defined where the data of supplier and input obtained from the bill of material from various vendors. The

interview with the head of the Quality Assurance unit is also conducted to understand the detailed process of manufacturing the Electric Lovina Bed 3 Motor. The following is a SIPOC diagram that explains the flow of the production process :

In Figure 1, it is noted that the production process starts from the materials provided by the supplier as the input for the process to manufacture the electric Lovina bed three motors. The process is categorized into pretreatment, assembly, welding, painting, final inspection, and packaging. Based on the observations and quality data rework report, the defect could be found in the process and input phase. The weakness was caused by the material defect provided by the vendor.

Measure

This stage will determine the DPMO (Defect Per Million Opportunities) value and the Sigma Level value using the defective product and monthly production data obtained from the final inspection and PPIC (Production Planning and Inventory Control) measure the company's current performance. Then, it can produce the DPMO value and its sigma level.

The results of DPMO values in Figure 2 and Six Sigma values in Figure 3 are based on the calculation of DPMO and Sigma Values in Table 3, which show the value from May to October with the average DPMO of 58558.56 and an average sigma value of 3.07. It is noted that the value is still not sufficient because the value is

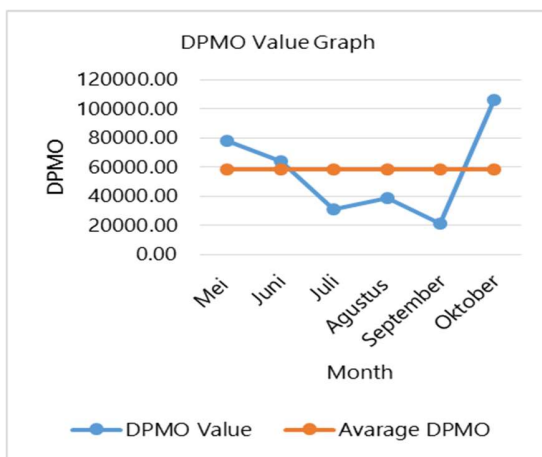


Figure 2. DPMO Value Graph

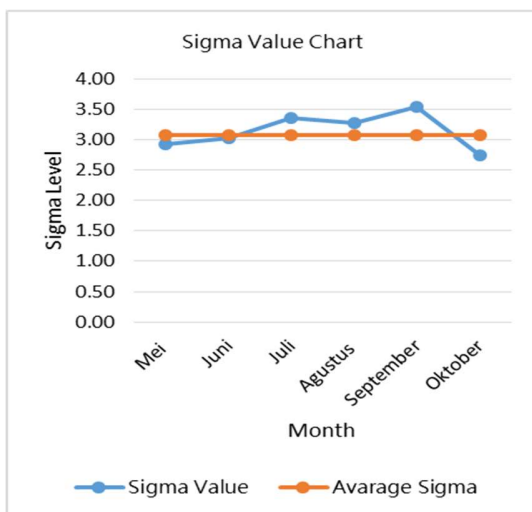


Figure 3. Sigma Value Chart

still far from 6 Sigma, but the value is already above the industry average in Indonesia (2 Sigma). Thus, the Company always necessary to improve the quality of the process; even the value of DPMO value is better than the industry average in Indonesia (308,358), but it is still far from the average value in the USA (6,210) and Japan (233). (Gaspersz, 2002).

Analyze

At this stage, an analysis of a fishbone diagram is conducted to identify the factors that cause the defect. It is categorized into a type of defect such as the functional, complete components, welding, material, painting, appearance, or aesthetics. Direct observation, interview with the operator and the head of the Quality Assurance (QA) unit is also applied to support the analysis.

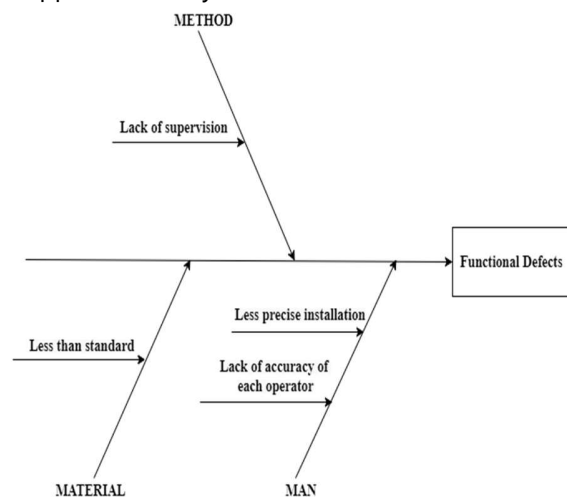


Figure 4. Fishbone Diagram of the Causes of Functional Defects

In Figure 4, three factors cause functional defects, such as man aspect due to the operator's lack of accuracy and precision to assemble the components, method aspect due to the lack of supervision, and material aspect because the material's quality is less than standard.

In Figure 5, three factors cause component completeness defects, such as man aspect, due to each operator's lack of accuracy to implement SOP, which impacts some components that are not installed. Furthermore, the material and method aspect due to improper scheduling also

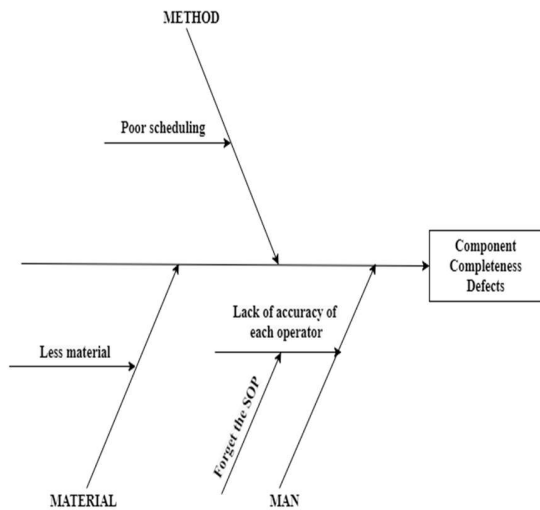


Figure 5. Fishbone Diagram of the Causes of Component Completeness Defects

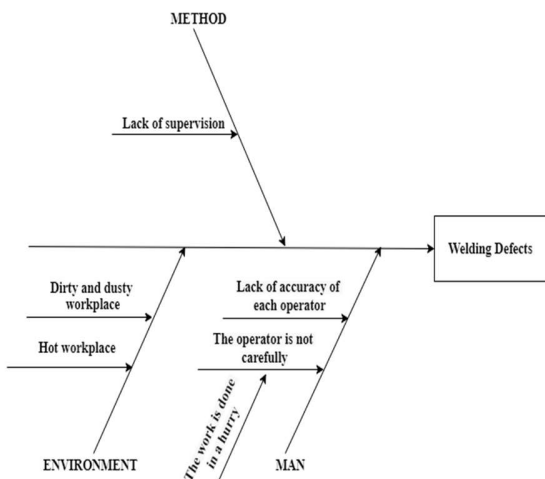


Figure 6. Fishbone Diagram Causes of Welding Defects

could affect the arrival of the material, and then the stock material could be depleted in the warehouse.

Figure 6, three factors that cause welding defects, such as the man aspect due to the lack of accuracy of each operator to perform welding and grinding. Furthermore, the methods aspect due to the operator and environment aspect's lack of supervision due to the dirty, dusty rooms, and hot room temperatures also affect the welding defect.

Figure 7, 3 factors cause material defects such as man aspect due to lack of operator accuracy to inspect components from vendors

and lack of caution during the production process. Then, the methods element due to the ineffective inspection systems and material aspect because it is less than standard.

In Figure 8, four factors cause painting defects such as man aspect due to lack of operator accuracy to inspect the components to be processed, then methods aspect due to the lack of inspection before the painting, also material aspect due to unclean material, and environments aspect due to the dirty and dusty workspaces.

In Figure 9, five things cause appearance/aesthetic defects, such as man aspect due to lack of operator accuracy and

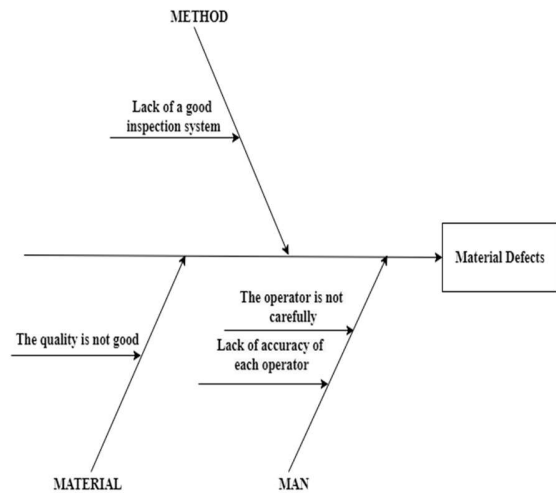


Figure 7. Fishbone Diagram of the Causes of Material Defects

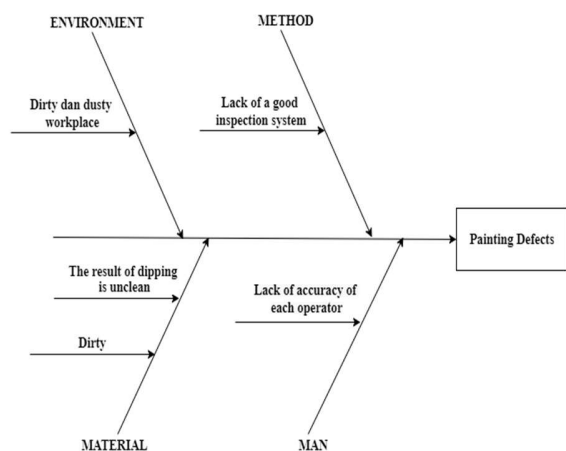


Figure 8. Fishbone Diagram Causes of Painting Defects

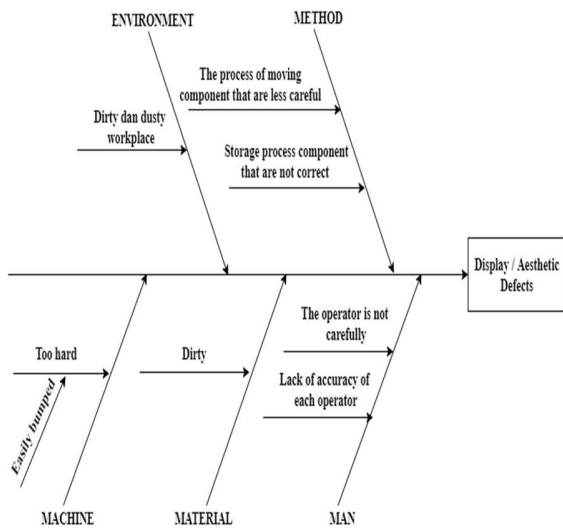


Figure 9. Fishbone Diagram of Cause of Display / Aesthetic Defects

methods aspect due to the material transfer process and the storage of components. The material aspect is also due to the material cleanliness and environment aspect due to the dirty and dusty workspace. Then, machines with equipment that is too hard can cause a collision.

Improve

Failure Mode and Effects Analysis (FMEA) is conducted to find a prioritized corrective action plan by identifying and assessing the risks associated with potential failure. Risk assessment is also performed by measuring the severity, incidence, and detection factors. These three values were obtained from interviews with the head of quality control in the company. Thus, it is possible to determine the probability of consequences of each cause of a defect and the most influential causes of defective products through the amount of the Risk Priority Number (RPN) for each potential reason (Kosina, 2013).

The calculation is conducted based on the stages of the production process at each station. The priority of improvement measures will have an extensive impact because repairs are determined at each station.

In Table 4, the Risk Priority Number (RPN) calculation was determined. The more excellent RPN value for each potential cause indicates, the more priority it needs to mitigate so that the product results are not found defects. Proposed

improvements based on preference to reduce the waste of time and product defects that often occur include the following:

1. At the work station of Assembly, the highest RPN value is obtained for materials that have been used up in the warehouse with an RPN value of 405. If this happens, it can cause component shortages during the Assembly process, and components cannot be installed into a product included in the defective category completeness of components. Therefore, corrective action is needed to overcome or reduce the problem by increasing the scheduling program and component inventory.

2. In the work station of painting, the highest RPN value is found in dirty and dusty workspaces with an RPN value of 324. If this happens, it can cause the painting's results to become lumpy, included in the painting defect category. Therefore, corrective action is needed to overcome or reduce the problem by providing the operator with information and supervision related to maintaining product cleanliness.

3. At the welding workstation, the highest RPN value is obtained in the grinding process, which is not optimal due to lack of supervision with an RPN value of 324. If this happens, it can cause sharp welding results that are included in the welding defect category. Therefore, corrective action is needed to overcome or reduce the problem by providing operators' supervision and standards.

Of the three potential causes of defects in the three work stations, it can be seen that the Assembly process is a work station that has priority over welding and painting work stations because it has the most significant RPN value. The effect of the potential causes of defects will be more significant.

Control

Using problem-solving by standardizing it, making the standard work guidelines for the issues encountered and the solution found. Then do the documentation and disseminated it to all company employees. This is so that the same problem does not recur.

Precautions so as not to cause the same

defective product. So do the documentation to be used as a standard and learning of the

Table 4. Failure Mode and Effect Analysis

Process Step / Input	Potential Failure Mode	Potential Failure Effects	Potential Cause	Score			RPN	Suggested Actions
				S	O	D		
Welding	Welding defects	Perforated welding and sharp welding	Lack of accuracy of the operator	5	6	6	180	Provision of supervision and specified standards for operators
			The grinding process is not optimal due to a lack of supervision	6	7	5	210	
			Dirty and dusty rooms and hot room temperatures	3	7	9	189	
Painting	Painting defects	Some sides have not been maximally exposed to paint	Lack of operator accuracy to inspect the components to be processed	3	10	9	270	Updating the painting system and training for operators
			Lack of examination before being painted	4	6	6	144	Check and clean the material before being painted
		Clot	Unclean material	4	8	7	224	
			Dirty and dusty workspaces	4	9	9	324	Operators are given information and supervised to maintain product cleanliness
Assembly	Functional defects	Side guard rocking	Lack of precision during installation	5	6	5	150	Provide training against predetermined standards
			Lack of supervision	6	7	5	210	
	Dirt clings	Dirty component	The cleanliness of the workspace is poorly maintained	4	10	9	360	Operators are given information and supervision regarding product cleanliness
	Vendor component mismatch	Rough plastic	The process of checking goods from outside is not good	6	5	6	180	Strict supervision of vendor products
	Specifications do not match.	Side guard rocking	The operator does not install each component according to precision	5	6	5	150	Provide learning against predetermined standards
Assembly	Lack of checks on side guard springs from vendors	Heavy side guard lock	Side guard springs that are not functioning optimally	6	6	5	180	Inspection of ordered side guard springs
Welding	Welding defects	Sharp welding	The grinding process is not optimal due to a lack of supervision	6	7	5	210	Provision of supervision and specified standards for operators
		Perforated welding	The operator is less thorough	5	6	6	180	
Pretreatment	Dirt still sticking	Components are still dirty	Dipping spots that are rarely cleaned and lack inspection after dipping	4	4	6	96	Perform cleaning and scheduling of dippings after repeated use and supervising operators to check the results of dippings
	Dust clings	Layered grainy	Dusty painting place	2	4	5	40	Clean the workspace and maintain cleanliness

problems that have been faced and with the solution. This system will make it easier for both new employees and old employees and produce

useful information in studying quality problems in the future so that effective improvement actions can be taken.

Table 4. Failure Mode and Effect Analysis (continued)

Process Step / Input	Potential Failure Mode	Potential Failure Effects	Potential Cause	Score			RPN	Suggested Actions
				S	O	D		
Painting	Components are still dirty	Clot	Components in the immersion stage that have less clean results	4	6	6	144	Check before entering the painting stage
	Painting is not optimal.	Some sides have not been maximally exposed to paint.	The results of the paint are not evenly distributed to small corners on complex components	3	10	9	270	Updating the painting system and learning for operators
Functional defects		Side guard rocking	Lack of accuracy of each operator in installing each component	5	6	5	150	Provide training against predetermined standards
		Heavy side guard lock	Components less than standard	6	6	5	180	Inspection of ordered side guard springs
Component Completeness Defects		Lack of components	Lack of accuracy of each operator in understanding the SOP	2	8	8	128	The component grouping for each type of product inbox
			The scheduling system is not good	3	10	8	240	Improve scheduling and inventory programs
Material defects		Rough plastic	Material has run out in the warehouse	5	9	9	405	Strict supervision of vendor products
			Inspection systems that are not effective	6	5	6	180	Less than standard
Material defects		Rough plastic	Lack of operator accuracy in examining components originating from vendors	6	5	6	180	
			Blisters	Lack of caution during the production process	3	5	5	75
Display / Aesthetic Defects		Dirty component	Lack of component transfer process and the storage of components	4	5	9	180	Operators are given information and supervision regarding maintaining product cleanliness
			Dirty and dusty workspace	4	10	9	360	
Display / Aesthetic Defects		Blisters	The cleanliness of the material	4	7	9	252	
			Lack of operator accuracy in treating components	3	5	5	75	Information about handling details is given
			The equipment that is too hard can cause a collision	3	7	5	105	

IV. CONCLUSION

Based on the analysis results and discussion to improve the quality of products Electric Lovina Bed 3 Motor, it's suggested to do the action based on priority. First, the operator and workers begin to get used to handling the product carefully and maintain the cleanliness of a product and its workspace. Second, the improvements to the painting system because the process of painting process must be maximized so that no reworked products to repaint the powder will cost a lot of money or spray because it will affect the paint's quality. Third, the supervisor routinely checks the operator's work at each work station, especially in the grinding and assembly, so that operators work carefully and optimally. Fourth, the dipping party more routinely supervises the dipping results and the immersion site if it is too dirty, then cleaning is done so that the results can be maximally clean and there is no more dirt attached.

So that based on these results, the company can implement it directly in the field and will have an impact on improving the quality of the products Electric Lovina Bed 3 Motor. Then it will speed up the completion of a product without having to wait for the product to be repaired if defects are found.

Standardization and documentation are needed, so the proposed improvements used are used as work guidelines for both old and new workers, so they can still know how to solve defective products, so the possibility of defects will be reduced defects. That way will also be able to improve the quality of Electric Lovina Bed 3 Motor products.

With this research, researchers hope to contribute to managing hospital equipment products' quality, especially beds that require supervision to produce the best quality products. For further research, the authors suggest that research can lead to procedures that must be regulated so that quality control can be appropriately applied, especially for hospital equipment products or applied to several companies both large and small scale and

examine how effective corrective actions to improve the quality product of this research. Furthermore, data can be collected and organized so that it can be applied to test the effectiveness of corrective actions.

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