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Aplication of Six Sigma & FMEA Methods to Improve The Quality of Laminated Tube Packaging

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Abstract

PT Lamipak Primula Indonesia is a company that produces various packaging made of plastic. The main product of PT Lamipak Primula Indonesia is toothpaste laminated tube packaging. PT Lamipak Primula Indonesia wants to minimize defects in products to minimize waste, reduce costs, increase efficiency, and maximize profits. This can also increase customer confidence in the product. PT Lamipak Primula Indonesia improves the quality of its products by applying Six Sigma with the DMAIC method. In this study, DPMO of 15766 was obtained and then converted to a sigma level of 3.7 which shows that the sigma level is below the 6 sigma level. This shows the achievement of sigma that has not been consistent and still shows the need for quality improvement in the laminated tube packaging production process in order to achieve zero defects. Based on FMEA analysis, it shows that the most significant failure occurs in machine conditions that cause defective shoulders with a value RPN of 210. This failure is caused by the lack of regular machine inspection, by the machine not being supervised in realtime, not following the SOP and the lack of worker skills.

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

1. Introduction

One of the main challenges in producing a product is minimizing product defects that can affect performance, customer confidence, and operational efficiency. In the specific case of packaging industry such as laminated tubes for toothpaste at PT Lamipak Primula Indonesia, various defects such as tube deformation, melting defects, shoulder defects, and print misses often arise due to variability in the production process, raw materials, machines, or work methods. Six sigma and FMEA methods have proven to be effective approaches in risk management and quality control. Six sigma focuses on reducing process variation through a data-driven approach and the DMAIC (Define, Measure, Analyze, Improve, Control) cycle, while FMEA enables systematic identification of failure risks to reduce the impact and chance of future problems. Therefore, the discussion of the implementation of Six Sigma and FMEA in the production process is important to identify problems, design improvement solutions, and make a real contribution to the development of the company's quality management system [1], [2].

2. Research Metodology

2.1. Define

Define is the first operational stage in the six sigma quality improvement method. At this stage, it is determined the proportion of defects that are the most significant cause of damage which is the source of failure of a product. The define stage is the first operational step in the six sigma quality improvement program. The goal is to identify the object under study and determine the purpose of the improvement activity [3], [4]. For this purpose, the number of production, the number of defective products of the product and the identification of CTQ which contains the types of defects that occur at PT Lamipak Primula Indonesia are collected. In this stage, a SIPOC diagram is used to determine the processes involved, the sequence of processes and process interactions and what things are involved in the production process.

2.2. Measure

The measure stage is the stage of determining Critical to Quality, calculating the sigma value and Defect Per Million of Opportunity (DPMO) value based on conditions before implementation. Is the second operational step in the Six Sigma quality improvement program. Consists of identifying research objects and identifying Critical to Quality (CTQ) variables [5]. This step is done so that the company's performance in production can be known. The following formula is used:

$$DPU = \frac{Jumlah\ cacat}{Jumlah\ produksi} \quad (1)$$

$$DPO = \frac{Jumlah\ cacat}{Jumlah\ produksi\ x\ peluang\ kerusakan} \quad (2)$$

$$DPMO = DPO\ x\ 10^6 \quad (3)$$

Where :

DPU = Defect per Units
DPO = Defect per Opportunities
DPMO = Defect per Million

2.3. Analyze

Analyze is the stage to determine the factors that most affect the process. In this research, the analysis stages used are pareto diagrams, histograms, fishbone diagrams and failure mode and effect (FMEA) [6]. Data obtained through interviews with staff.

2.4. Improve

This stage aims to make improvements and improvements so that the causes that have the potential to cause defective products are reduced, where in this stage an analysis will be carried out using implementation tools which include the Five-M Checklist and 5W + 1H. The Improve stage in Six Sigma aims to achieve continuous improvement in the process or system being analyzed. This is done with a data-driven approach and using relevant Six Sigma tools and techniques to achieve better results and reduce variability in business operations [7], [8].

2.5. Control

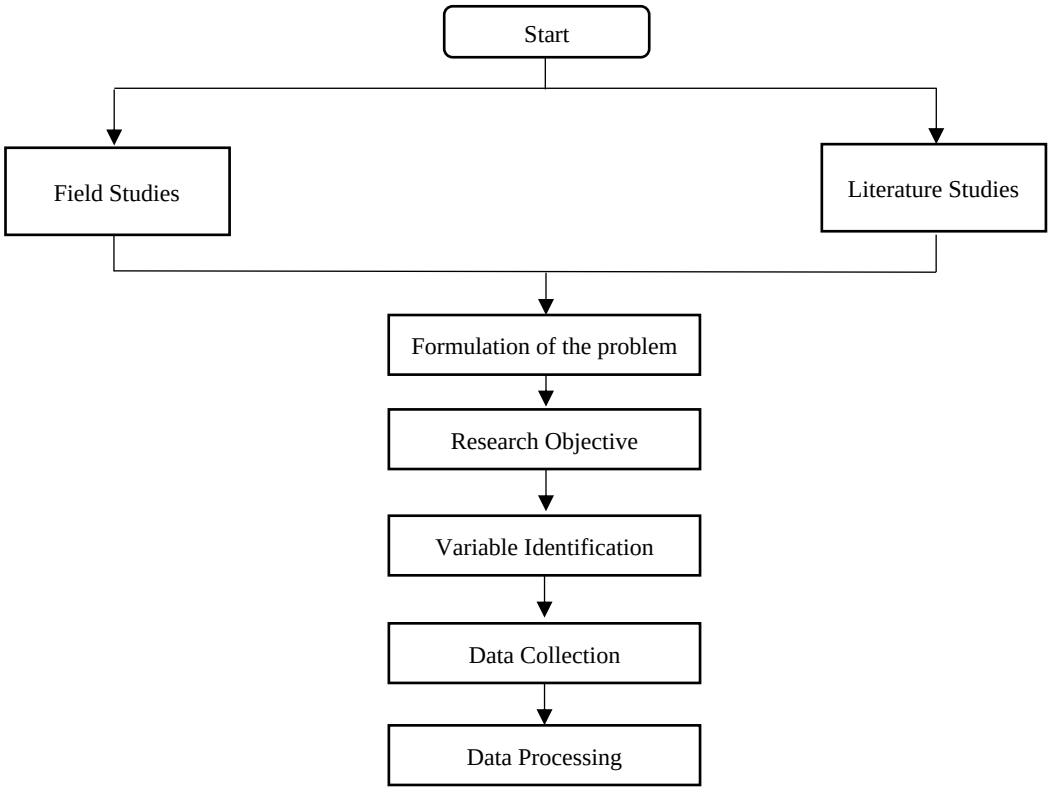
Control is the last operational stage in the Six Sigma quality improvement method. However, in this research, control cannot be implemented because the improve stage is only limited to proposals, so only measurement results are documented to serve as work guidelines. As part of the Six Sigma approach, monitoring is necessary to ensure that the desired results are in the process of being achieved. The results of the improve stage must be implemented within a certain period of time to be able to see the effect on the quality of the products produced [9], [10].

2.6. Data Sources and research variables

The object of research is an object related to the product under study, the object under study is the quality of laminated tube packaging.

1. Independent variables or those that affect the dependent variable. In this research it's played by tube deformation, welding defect, defective shoulder, and printing misalignment
2. The dependent variable is the effect variable or the one affected by the independent variable. In this research it's played by the quality of laminated tube packaging of tooth paste

2.6. Flowchart



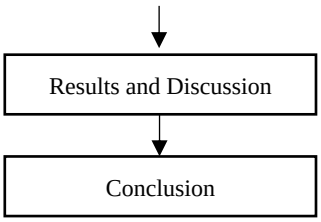


Fig. 1: Flowchart

3. Results and Discussion

The define stage is the first stage in the six sigma method. In this stage, the object under study will be identified process, identification of critical work stations, identification of defects and then made CTQ and SIPOC diagrams. The problem often faced by this company is the high occurrence of defects. Determination of the research object is focused on the production process of toothpaste laminated tube packaging in September 2024.

Table 1: Total Production and Defect of Laminated Tube Packaging on September 2024

Type of Defect	Total
Tube Deformation	51472
Welding defect	154416
Defective Shoulder	25736
Printing Misalignment	102944
Total Defect	334567
Total Production	5463252

Table 2: Define Laminated Tube Packaging

Component	Description
Business Case	PT Lamipak Primula Indonesia is a company engaged in the production of lamintaed tube and plastic packaging. The company is located at Jl. Sawunggaling No. 26, Gilang, Taman, South Gilang, Gilang, Kec. Taman, Sidoarjo Regency, East Java 61257.
Problem Definition	In this case the problem that will be discussed on toothpaste tube packaging products is how to make product improvements by paying attention to the quality of the product itself. The defects that occur in this production are tube dents, critical welding, shoulder jembret, and print slippage.
Project Scope	The object to be studied is a company that produces tube packaging. The scope of this research is a product quality improvement action strategy.
Goal Statement	To determine the defect rate, identify the factors causing defects and recommend corrective actions for toothpaste tube packaging products.
Project Timeline	The period of this research is for fifteen days which was conducted on September 1, 2024 to September 15, 2024.

Process description : Laminated Tube Packaging of Toothpaste				Date Completed:15/11/2024
Completed by: Hafizh Hazmi Al Fauzi				
Supplier	*Input*	*Process*	*Output*	*Customer*
Supplier Print Web	*Print Web*	*Printing*	*Laminated Tube Pacakging*	*Toothpaste Factory*
Supplier Ink	*Ink*	*Seaming*		
Supplier Cap	*Cap*	*Cutting*		
		Injection moulding		
		Capping		
		Packing		

Fig. 2: SIPOC Diagram

Suppliers at PT Lamipak Primula Indonesia are parties that provide materials for the toothpaste laminated tube packaging production process, namely web print suppliers, ink suppliers, and stamp suppliers. web print suppliers provide web print raw materials for processing. The supplier of auxiliary materials provides auxiliary materials in the production process of laminated tube packaging, namely ink and stamp. Furthermore, the materials from these suppliers are used as input for the production process of laminated tube packaging at PT Lamipak Primula Indonesia.

The production process of toothpaste laminated tube packaging production at PT Lamipak Primula Indonesia starts with the printing process, namely printing images on the web print according to customer requests. The printed web will go through the seaming process, which is the process of rolling and gluing the web print into a laminated tube. Laminated tube is still in the form of long rolls so a cutting process is needed, namely cutting according to customer demand specifications. Laminated tube that has been cut will be injected with plastic to make the shoulder. The shoulder on the laminated tube is a component that connects the laminated tube with the packaging lid thread. The laminated tube packaging is ready to be closed using a capping machine in the capping process. The last process of laminated tube packaging production is the packaging process. Laminated tube packaging is packaged using cardboard boxes and stored in a storage warehouse which will later be distributed to customers. PT Lamipak Primula Indonesia's customer is a toothpaste factory.

t the measure stage, the calculation of process performance is carried out with the first step, namely determining CTQ. This measurement stage is very important in improving quality, because it can be known the state of the company from existing data so that it becomes a benchmark or basis for analysis and improvement. In the production process of toothpaste laminated tube packaging, it is found that the results that affect the high number of rejects are tube deformation, welding defect, defective shoulder, and printing misalignment.

Table 3: Critical to Quality

CTQ	Criteria	Description
CTQ-1	Tube Deformation	laminated tube packaging for toothpaste has deformation or dents on its surface
CTQ-2	Welding defect	the gluing point (seam) on the laminated tube packaging for toothpaste has an uneven or wavy surface.
CTQ-3	Defective Shoulder	the shoulder part of the laminated tube packaging for toothpaste, which functions as a place to attach the cap, has an abnormality in the form of material that exceeds the mold limit
CTQ-4	Printing Misalignment	The printed image or text on the toothpaste laminated tube packaging does not match the desired position or design.

Based on the results at the define stage, measure is the second operational step in order to improve quality in the DMAIC method. Baseline performance measurements are expressed in defects per million opportunities (DPMO) and sigma levels. defects per unit, defects per opportunities, defects per millions and sigma values from the company based on reject data from September 2024.

Table 4: Value of DPU, DPO, DPMO, and Six Sigma

TOP	0.063
DPU	0.016
DPMO	15766.3
Six Sigma	3.72

From the calculation of DPMO and sigma values in table 4, it is known that the numbers in the table show a DPMO value of 15766.3 and a six sigma value of 3.72, which means that the six sigma value is still far from the ideal number of 6 sigma. From the results of the measure process, the next step is the analysis process which is the third operational step in the six sigma quality improvement program. In this stage, what needs to be done is to analyze the results that will be obtained at the measure stage. And identify the sources and root causes of defects or failures.

At the analyze stage, several things will be done, namely identifying the types of defects that occurred in September 2024 and prioritizing which defects have the greatest contribution to reducing the six sigma value using the help of seven tools. By using Pareto diagrams, it is known that the types of defects that cause a decrease in quality in the production of laminated tube packaging.

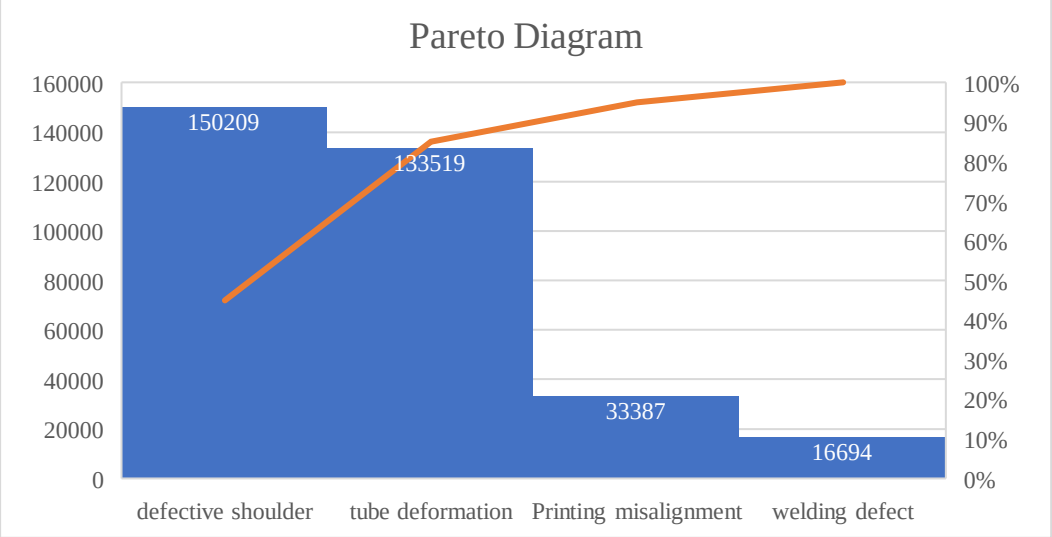


Fig. 3: Pareto Diagram

From the pareto diagram that has been made, it can be seen the most common type of defect is defective shoulder with a percentage of 45% with a total defect of 150209. So it can be concluded that the highest defect in laminated tube packaging is defective shoulder and must be evaluated immediately. From the 4 dominant types of defects that have been identified, the next step is to identify the cause of the defect problem using a fishbone diagram. Five categories of factors that cause defects were identified, including human factors, method factors, environmental factors, machine factors, and material factors. Figure 4 shows the fishbone diagram.

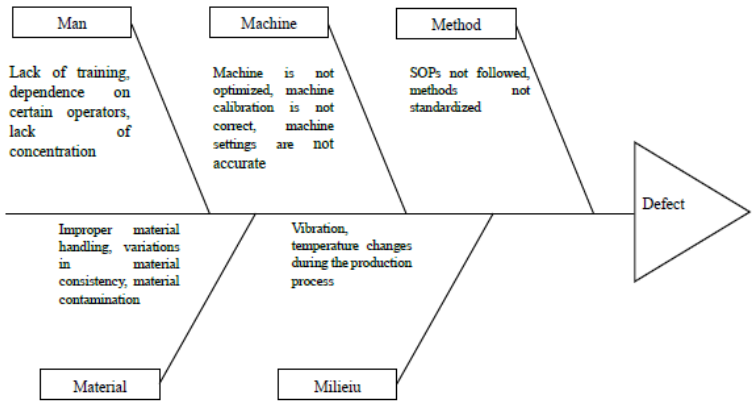


Fig. 4: Fishbone Diagram

There are 5 factors that cause defects, which include human, machine, method, material, and natural factors. In human factors, the factors that cause defects are lack of training, dependence on certain operators, lack of concentration. In the machine factor, the factors that cause are lack of non-optimal machines, improper machine calibration, inaccurate machine settings. In the method factor, the contributing factors are SOPs are not followed, methods are not standardized. In the material factor, the contributing factors are improper material handling, variations in material consistency, material contamination. And on natural factors, the contributing factors are Vibration, temperature changes during the production process.

The improve stage is carried out to find effective improvements based on the types of CTQs that have the most potential to occur. The tools to be used at this stage are the five m checklist, 5W + 1H and failure mode and effect analysis. In this improvement stage, a Six Sigma quality improvement action plan is implemented, through improvements to the sources that cause defective products. The improvement plan is carried out on all sources that have the potential to create defective products.

Five M-Checklist focuses on five key factors involved in the process, namely man, milieu, method, machine, and material. To identify the causes of product defects in laminated tube packaging of toothpaste products that are not statistically controlled, the Five M-Checklist is used here by making subgroups of the causes of product defects so that it can make it easier to understand the overall problem.

Table 5: Analyzing problem using five m checklist

No	Factor	Problems	Troubleshooting
1	Man	• Lack of training • Dependence on a particular operator • Lack of concentration	• Conduct periodic training • Provide a checklist of work guidelines • Rewarding operators with good performance
2	Machine	• Machine is not optimized • Improper machine calibration • Inaccurate machine settings	• Monitor machine parameters in real time • Run the machine according to capacity
3	Method	• SOP are not followed • Methods are not standardized	• Apply consistent methods • Evaluate and revise SOPs
4	Material	• Improper material handling • Variation in material consistency • Material contamination	• Proper material handling • Conduct audits of supplier
5	Milieu	• Vibration • Temperature changes during the production process	• Control the temperature of machines and materials

5W1H (What, Why, Where, When, Who and How) analysis was conducted to formulate corrective actions for the large number of defective bracket products. The following are the results of the 5W1H analysis for the dominant defect-causing factor, namely the machine factor. What asks what happened? Why asks why it happened? When asks when the event occurred? Where asks where the event occurred? Who asked who was involved in the event How asked how to fix it? In this improve stage, it is a stage that serves to make proposals for improvement of six sigma quality. In this case, researchers implemented the 5W + 1H and Five step plan. By controlling defective products properly, operator skills and awareness must be improved, supervisors are responsible for defective products in each area.

Table 6: Description 5W + 1H

Types	5W + 1H	Description
Main objective	What is the purpose of improving?	To improve the product quality of toothpaste laminated tube packaging
Location	Where are the sources of defects in the production of toothpaste laminated tube packaging?	On the production floor of making toothpaste laminated tube packaging at PT. Lamipak Primula Indonesia
Cause	Why does this happen?	Toothpaste laminated tube packaging production defects can occur from several factors, the first is the human factor of operator negligence causing product defects, material factors of improper material handling, machine factors negligent in monitoring machine parameters, method factors in the absence of SOPs and the last is environmental factors, namely the lack of temperature control of machines and materials.
Man	Who will work on this action plan?	Head of production and operator

Implementation	When is the repair of toothpaste laminated tube packaging defects?	Implementation is done after improving the human factor is done
Corrective actions	What is the method of improvement?	Human factors: Conduct periodic training Providing work guidance checklists Machine factors: Monitor machine parameters in real time Method factor: Implement a uniform method Evaluate and revise SOPs Material factors: Proper material handling Environmental factors: Controlling machine and material temperatures

In the control stage, the implementation of corrective actions is carried out, then evaluated whether the actions have been effective in improving the company's production control. The corrective action is said to be effective if the resulting sigma value is greater than the sigma value before implementing the corrective action. If the corrective action is effective, a Standard Operating Procedure (SOP) is made and informed to all stakeholders. If the corrective action is not effective, another evaluation is carried out and a new, better corrective action is formulated. In addition to making efforts to improve production quality control, supervision of the production process also needs to be improved to analyze whether the sugar production quality control measures taken can still be carried out or need to be replaced and developed for the better.

The results of the improve stage must be applied within a certain periode of time to see the effect on the quality of the products produced. Actions that need to be taken are giving rest time for a few minutes after every few hours of work so that workers do not experience overworked which causes a decrease in concentration. Conduct QC inspections strictly and thoroughly to avoid product defects. Conducting periodic training for workers so that they are more proficient and thorough in making products. Perform maintenance before the machine is run, periodic machine changes every few years/every time the machine is not suitable for use. Comply with the SOP that has been made to avoid things that can interfere with the course of production.

After knowing the problems that exist in the business process, then identification of the most dominant problems can be done, where these problems need to be improved to obtain a more effective and efficient business process. The identification of these problems can be done using the Failure Mode and Effect Analysis (FMEA) method. Failure Mode and Effect Analysis (FMEA) is a systematic method that aims to identify the cause of a problem that occurs and prevent problems in the process before the problem can occur. The following is a table of Failure Mode and Effect Analysis (FMEA) Risk Priority Number (RPN) assessment to identify the causes of problems in the business process.

Table 7: Failure Mode and Effect Analysis

Mode of failure	Effect of failure	Causes of failure	Current control	S	O	D	RPN
Tube Deformation	laminated tube packaging for toothpaste has deformation or dents on its surface	Man	Organize periodic training	7	3	2	42
		Material	Proper material handling		4	2	56
		Machine	Monitor machine parameters in real time		6	5	210
		Method	Evaluate and revise SOP		5	3	105
		Milieu	Control machine and material temperatures		3	2	42
Welding Defect	the gluing point (seam) on the laminated tube packaging for toothpaste has an uneven or wavy surface.	Man	Provide work guidance checklist	4	2	3	24
		Material	Proper material handling		3	2	24
		Machine	Monitor machine parameters in real time		4	4	64
		Method	Implement uniform methods		4	3	48
		Milieu	Controlling machine and material temperatures		4	4	64
Defective Shoulder	the shoulder part of the laminated tube packaging for toothpaste, which functions as a place to attach the cap, has an abnormality in the form of material that exceeds the mold limit	Man	Provide work guidance checklist	6	2	2	24
		Material	Proper material handling		2	2	24
		Machine	Monitor machine parameters in real time		5	4	120
		Method	Implement uniform methods		3	2	36
		Milieu	Controlling machine and material temperatures		6	4	144
Printing Misalignment	The printed image or text on the toothpaste laminated tube packaging does not match the desired position or design.	Man	Provide work guidance checklist	4	4	3	48
		Material	Conduct supplier audits		5	3	60
		Machine	Run the machine according to capacity		5	3	60
		Method	Apply uniform methods		5	2	40

Mode of failure	Effect of failure	Causes of failure	Current control	S	O	D	RPN
		Milieu	Control machine and material temperature		5	4	80

Based on the FMEA analysis that has been carried out, there are several priority improvements that can be made in the production process of laminated tube packaging for toothpaste at PT Lamipak Primula Indonesia. The analysis shows that the most significant failure occurs when the machine is not monitored in real time with a Risk priority number (RPN) value of 210 with a percentage of 16%. This failure is caused by the machine not being supervised in real time, not following the SOP and lack of worker skills. The proposed improvement solution is to tighten machine supervision, periodic employee training and evaluate SOPs in order to prevent this failure.

4. Conclusion

In the DMAIC analysis (Define, Measure, Analyze, Improve, Control) the results obtained are by testing the quality of laminated tube toothpaste packaging in the production process resulting in a failure of 334567 units, a Defect Per Million Opportunities (DPMO) value of 15766 and then converted to a sigma level of 3.7 which indicates that the sigma level is below the 6 sigma level. It can be explained that the possibility of damage is 15766 for a million production. This shows an inconsistent pattern of DPMO and sigma achievement, which indicates that the production pattern has not been managed properly and still needs improvement and there is a need for quality improvement in the laminated tube packaging production process in order to achieve zero defects.

Based on the FMEA analysis that has been carried out, there are several priority improvements that can be made in the production process of laminated tube packaging at PT Lamipak Primula Indonesia. This analysis includes four main types of defects, namely tube deformation, welding defect, defective shoulder, printing misalignment. Each type of defect is analyzed to identify failure modes, causes, and applicable improvement solutions. The analysis shows that the most significant failure occurs in machine conditions that cause defective shoulder with a Risk Priority Number (RPN) value of 210. This failure is caused by the lack of regular or scheduled machine inspections, by machines not being supervised in real time, not following SOPs and lack of worker skills resulting in defective shoulders. The proposed improvement solution is to conduct regular or scheduled machine inspections to ensure the condition of the machine remains optimal, is to tighten machine supervision, periodic employee training, evaluate SOPs in order to prevent this failure and prevent the occurrence of this failure.

From the research conducted, the conclusion is obtained in the form of recommendations for PT Lamipak Primula Indonesia to continue to improve the quality of its products. Things that can be done include the need to create an SOP that can be applied during production activities, conduct regular monitoring and provide understanding for workers regarding the importance of quality control so that they can contribute significantly to realizing zero defects in laminated tube packaging production activities.

References

[1] Waluyo, W., Sholihin, S., Permana, R. A., Firmanti, T. A., & Permatasari, Y. I. (2019). Application of Six Sigma Method in Infection Prevention and Control in Hospital: A Systematic Review. Journal of Health Research "SUARA FORIKES" (Journal of Health Research "Forikes Voice"), 11(1), 108-112. http://dx.doi.org/10.33846/sf11123

[2] Zulkhulaifah, J. A., & Apriliani, F. (2024). Application of Six Sigma and Define, Measure, Analyze, Improve, Control (DMAIC) Method for Green Tire Shortage Analysis at PT Merpati Putih. Factory Journal of Industry, Management and Industrial Systems Engineering, 2(3), 119-133. https://doi.org/10.56211/factory.v2i3.495

[3] Ghiffari, I., Harsono, A., & Bakar, A. (2013). Six Sigma Analysis to Reduce the Number of Defects at the Screen Printing Work Station (Case Study: CV. Miracle). Reka Integra, 1(1).

[4] Sepriandini, Frizkia, and Yustina Ngatilah. "Application of six sigma method and failure mode and effect analysis (fmea) in analyzing the quality of newspaper products at pt. xyz balikpapan." tekmapro: journal of industrial engineering and management 16.02 (2021): 57-60.

[5] Hanifah, P. S. K., & Iftadi, I. (2022). Application of Six Sigma Method and Failure Mode Effect Analysis for Improvement of Sugar Production Quality Control. Journal of Industrial Engineering INTECH Universitas Serang Raya, 8(2), 90-98. http://dx.doi.org/10.30656/intech.v8i2.4655

[6] Riandari, E., Susetyo, J., & Asih, E. W. (2022). Quality Control of Roof Tile Production Using the Application of Six Sigma Method and Failure Mode and Effect Analysis (FMEA). Rekavasi Journal, 10(1), 64-71.

[7] Pakki, G., Soenoko, R., & Santoso, P. B. (2014). Proposed application of six sigma method to improve cladding quality (Case study of weapon industry). JEMIS (Journal of Engineering & Management in Industrial System), 2(1).

[8] Rifaldi, M., & Sudarwati, W. (2024). Application of Six Sigma and FMEA Methods as an Effort to Reduce Defects in Bracket Products. Semnastek Proceedings.

[9] Wulandari, I., & Bernik, M. (2018). Application of six sigma quality control methods at heyjacker company. EkBis: Journal of Economics and Business, 1(2), 222-241.

[10] Caesaron, D., & Tandianto, T. (2015). Application of Six Sigma Method with DMAIC Approach to the Painted Body Handling Process of BMW X3 (Case Study: PT. Tjahja Sakti Motor). Research and Application of Industrial Systems and Engineering, 9(3), 182846.