Quality Control Analysis of Tube Sandwich Using Six Sigma Method in PT XYZ

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Abstract. Quality is one of the key aspects in every production activity. This research aims to improve the quality of the product on tubing machines used Six Sigma method with DMAIC phases. At phase define, the problem is found attubing machines with defects glue, printing, improper size and paper extension. In the measure phase, DPMO value is 3691 and sigma value is 4.18. In the analyze phase, the most dominant problem type of defects are glue and printing, will be analyzed according to machine, material and method factors. In the improve phase, the cause of problem will be sorted from the highest to the lowest uses FMEA method. Causes of glue problems are paper rolls are from many suppliers, the extruder needs time to be stable, the age of machine is old, piece of paper tucked in the knife bearing and not optimal material handling. The priority order of printing problems is not optimal material handling, piece of paper tucked in the knife bearing, the paper stuck in the printing unit, and ink are from several suppliers. Proposed improvements with 5W1H can be given according the order of root problems from the largest to the smallest.

Keywords: 5W1H, Defect Per Million Opportunities (DPMO), Failure Mode and Effect Analysis (FMEA), Quality, Six Sigma.

1. Introduction

Every manufacturing industry is required to provide the best in all aspects to meet customer needs and maintain customer loyalty. One aspect that is intended is the quality of the product. One method that can be used is the Six Sigma method. Six Sigma is a method for increasing productivity and profitability by applying methods from statistical tools to identify and measure waste and to show the steps for improvement. The Six Sigma concept itself is a continuous improvement effort in the hope of reducing defective products so that they can approach zero defects [1].

PT. XYZ is one of the construction materials companies in Indonesia, especially in the manufacture of cement. ABC Division is one of the supporting divisions at PT. XYZ which has the role to produce and provide all types of bags cement for PT. XYZ. ABC division has three types of machines used to produce cement bags. In December 2018 until February 2019 one of the machines in ABC division which is TM1 had a reject proportion of 0.63%, it means the reject proportion is higher than the reject standard of the company which is 0.40%. With the high proportion of reject products every month in the production of tube sandwiches, it will affect the costs incurred on the production floor.
Therefore, some actions and efforts are needed to reduce the high proportion of rejects on TM1 by first identifying the cause of the most dominant problem then analyzing and providing solutions for improvement of the problem. Therefore, the authors are interested in conducting research using the Six Sigma method to reduce the high proportion of rejects that occur in TM1.

2. Methods
Six Sigma is a method for increasing productivity and profitability. In addition, Six Sigma is an application of statistical tools to identify, measure and analyze the defects or wastage of a product and process so it leads to steps for improvement. In the result of Six Sigma application in the company it is hoped that this can overcome the production problems associated with product defects [1]. The phases of implementing quality improvement with Six Sigma consist of five phases, namely using DMAIC (Define, Measure, Analyze, Improve, and Control) [2].

2.1. Define
The first phase-define-serves as the platform for the team to get organized, determine the roles and responsibilities of each member of the team, establish team goals and milestones and review the process steps. The key points to be defined at this phase are the voice of the customer, the scope of the project, the cause and effect prioritization (a list that the team creates for pursuing the specific project based on cause and effect criteria) and project planning. The purpose of this phase is to set the foundations for the work ahead in solving a problem. This means that an excellent understanding of the process must exist for all team members, as well as complete understanding of the CTQ characteristics. After CTQ factors are identified, everyone in the team must agree on developing an operational definition for each CTQ aspect.

2.2. Measure
The second phase of the DMAIC model—measure—is when the team establishes the techniques for collecting data about current performance that highlights project opportunities and provides a structure for monitoring subsequent improvements. Upon completing this phase, we expect to have a plan for collecting data that specifies the data type and collection technique, a validated measurement system that ensures accuracy and consistency, a sufficient sample of data for analysis, a set of preliminary analysis results that provides project direction and baseline measurements of current performance.

2.3. Analyze
The third phase—analyze—serves as an outcome of the measure phase. The team at this phase should begin streamlining its focus on a distinct group of project issues and opportunities. In other words, this phase allows the team to further target improvement opportunities by taking a closer look at the data. This phase can be done by formulating some of the biggest causes of problems, so that the next phase (improve) becomes more focused and focused. Statistical analysis-based thinking plays a very important role at this phase. In this phase, it needs a thorough analysis so that in the next phase there is no error. Determine LCL, CL and UCL for control chart with these formula [3]:

\[ LCL = \bar{p}_0 - 3 \sqrt{\frac{\bar{p}_0 (1 - \bar{p}_0)}{n}} \]  

(1)

\[ CL = \bar{p}_0 \]  

(2)
\[
UCL = \bar{p}_o + 3 \sqrt{\frac{\bar{p}_o (1 - \bar{p}_o)}{n}} \tag{3}
\]

Where \(\bar{p}_o\) is the proportion of defective products determined by the company and \(n\) is sample size. The general form of DPMO function is:

\[
DPMO = \frac{DPU}{CTQ} \times 1.000.000 \tag{4}
\]

Where \(DPU\) is Defect Per Unit and \(CTQ\) is Critical to Quality of product. \(DPU\) is generally chosen as:

\[
DPU = \frac{Total\ Defect}{Total\ Production} \tag{5}
\]

The sigma value is obtained through the sigma conversion table from DPMO value.

2.4. Improve

The fourth phase—improve—aims to generate ideas; design, pilot and implement improvements; and validate the improvements. Perhaps the most important items in this phase are the process of brainstorming, the development of the "should be" process map, the review and/or generation of the current FMEA (failure mode and effect analysis), a preliminary cost/benefit analysis, a pilot of the recommended action and the preliminary implementation process.

2.5. Control

The fifth stage—control—is to institutionalize process or product improvements and monitor ongoing performance. This stage is the place where the transition from improvement to controlling the process and ensuring that the new improvement takes place. Of course, the transition is the transferring of the process from the project team to the original owner. The success of this transfer depends upon an effective and very detailed control plan.

3. Result and Discussion

The discussion in this study uses the Six Sigma method with the stages of DMAI (Define, Measure, Analyze, and Improve) to define, measure, analyze the causes of the high proportion of rejects found in TM1 so the improvements can be made in cause of potential failure.

3.1. Define

3.1.1. Identify the types of defects. The types of defects are determined based on references from the product check sheet as well as interviews with related parties. There are six types of defect: gluing, printing, mismatch size, paper extension, overlapping, and the number of plies are not appropriate.

3.1.2. Determine CTQ. CTQ determination is based on sample data taken by observing in the form of random sampling of 25 samples with a sample size of 560 pcs each. Total CTQ found was 4, gluing, mismatch size, printing and paper extension.

3.1.3. Determine the most dominant type of defect. From the sample data that has been collected, the most dominant type of defect can be determined by making a Pareto Diagram. Pareto diagram can show the most dominant type of defect so that treatment or repair can be started from the dominant cause first. The Pareto Diagram of defect is given in Figure 1.
Then the most dominant type of defect is due to gluing problems then followed by problems due to printing, mismatch size and paper extension. According to the 80:20 rule [4], this study will focus more on analyzing the types of defects caused by gluing and printing.

3.2. Measure

3.2.1 P control chart. By using equations (1), (2), and (3), the following results are LCL equal to 0, CL equal to 0.004 and UCL equal to 0.012. The P control chart is given in Figure 2.

![Figure 2. P control chart.](image)

All sample points are within the control limits. However, there are 13 sample points above the central line (CL) which in this case is the standard set by the company. Therefore, further analysis is needed.

3.2.2 Measure DPU, DPMO and Sigma value. DPU and DPMO values based on equations (4) and (5), sigma values based on conversion tables are given in Table 1.
Table 1. DPU, DPMO and Sigma value.

| No. | Number of Defect | CTQ | DPU   | DPMO   | Sigma |
|-----|------------------|-----|-------|--------|-------|
| 1.  | 2                | 1   | 0.0036| 3571   | 4.19  |
| 2.  | 4                | 2   | 0.0071| 3571   | 4.19  |
| 3.  | 1                | 1   | 0.0018| 1786   | 4.41  |
| 4.  | 4                | 3   | 0.0071| 2381   | 4.32  |
| 5.  | 2                | 1   | 0.0036| 3571   | 4.19  |
| 6.  | 4                | 3   | 0.0071| 2381   | 4.32  |
| 7.  | 3                | 1   | 0.0054| 5357   | 4.05  |
| 8.  | 2                | 1   | 0.0036| 3571   | 4.19  |
| 9.  | 6                | 3   | 0.0107| 3571   | 4.19  |
| 10. | 4                | 1   | 0.0071| 7143   | 3.95  |
| 11. | 2                | 1   | 0.0036| 3571   | 4.19  |
| 12. | 5                | 1   | 0.0089| 8929   | 3.87  |
| 13. | 3                | 2   | 0.0054| 2679   | 4.28  |
| 14. | 1                | 1   | 0.0018| 1786   | 4.41  |
| 15. | 1                | 1   | 0.0018| 1786   | 4.41  |
| 16. | 3                | 2   | 0.0054| 2679   | 4.28  |
| 17. | 5                | 2   | 0.0089| 4464   | 4.11  |
| 18. | 1                | 1   | 0.0018| 1786   | 4.41  |
| 19. | 2                | 1   | 0.0036| 3571   | 4.19  |
| 20. | 2                | 1   | 0.0036| 3571   | 4.19  |
| 21. | 3                | 1   | 0.0054| 5357   | 4.05  |
| 22. | 4                | 1   | 0.0071| 7143   | 3.95  |
| 23. | 2                | 1   | 0.0036| 3571   | 4.19  |
| 24. | 1                | 1   | 0.0018| 1786   | 4.41  |
| 25. | 3                | 2   | 0.0054| 2679   | 4.28  |
| Total|                 |     | 3691  | 4.18   |

3.3. Analyze

3.3.1 Analyze the causes of defect with Fishbone Diagram. Pareto diagrams show the dominant problem caused by the type of defect caused by gluing and printing problems. The further analysis of these two problems using Fishbone Diagrams is given in figure 3 and figure 4.

Figure 3. High reject of gluing Fish Bone.  
Figure 4. High reject of printing Fish Bone.
3.3.2. Determine failure modes with CFME. After the problem is found in the fishbone, find the root of the problem until there are no more causes. CFME is used before making FMEA as a development of the fishbone[5]. CFME due to gluing and printing issues are given in Figure 5 and Figure 6.

**Figure 5.** High reject of gluing CFME.

**Figure 6.** High reject of printing CFME.

3.3.3. Determine the problem priority with FMEA. The high reject of gluing FMEA is given in Table 2 and the high reject of printing FMEA is given in Table 3.

### Table 2. High reject of gluing FMEA.

| Factor       | Failure Mode                              | S  | Cause of Failure                                                                 | O       | Current Process Control                      | D  | RPN | Rank |
|--------------|-------------------------------------------|----|--------------------------------------------------------------------------------|---------|---------------------------------------------|----|-----|------|
| Machine      | Tucked pieces of paper                    | 7  | Cracks in the open knife pad can cause the pieces of paper get inside paper     | 5       | Change periodically the knife pad           | 5  | 175 | 4    |
|              | The machine is old                        | 6  | The machine was made in 1975. The machine specifications have not changed much   | 7       | Perform regular and scheduled maintenance | 6  | 252 | 3    |
|              | The extruder need time to be stable       | 7  | The machine need time to be stable. The extruder takes approximately a minute in | 6       | Eximining tube product, especially         | 7  | 294 | 2    |
|              | Paper roll from many supplier             | 8  | Order to distribute the glue stably. Paper roll from 4 different suppliers and  | 7       | the resin glue section                     |    |     |      |
| Material     | The different quality of glue             | 4  | Each suppliers has different quality. The quality of each shipment of resin      | 5       | Replace glue with specifications           | 4  | 80  | 6    |
|              | Unoptimal Material Handling               | 5  | Material Handling                                                               | 4       | Stir and filter the glue before use        | 6  | 120 | 5    |
Table 3. High reject of printing FMEA.

| Factor       | Failure Mode                                  | S | Cause of Failure                                                                 | O                      | Current Process Control                  | D | RPN  | Rank |
|--------------|-----------------------------------------------|---|----------------------------------------------------------------------------------|------------------------|------------------------------------------|---|------|------|
| Machine      | Tucked pieces of paper                        | 7 | Cracks in the open knife pad can cause the pieces of paper get inside            | 6                      | Change periodically the knife pad        | 5 | 210  | 2    |
| Machine      | Tucked pieces of paper in printing unit       | 8 | The paper cover the stamp from printing unit                                     | 6                      | Stop the machine and clear the printing unit | 3 | 144  | 3    |
| Method       | Unoptimal Material Handling                   | 7 | Unoptimal Material Handling                                                      | 6                      | Stir the ink before use                  | 7 | 294  | 1    |
| Material     | Ink from many supplier                        | 6 | Ink from 2 different suppliers and each suppliers has different quality          | 4                      | Replace ink with specifications          | 6 | 144  | 4    |

3.4. Improve

At this stage an analysis of an action plan is carried out through the improvement of the sources of defective products with the 5W1H method. 5w1h method aims to determine preventive and corrective actions from the cause of the problem [6]. High reject of gluing proposed improvement is given in Table 4 and high reject of printing proposed improvement is given in Table 5.

Table 4. High reject of gluing proposed improvement.

| Rank | Failure Mode                               | Proposed Improvement                                                                 |
|------|--------------------------------------------|--------------------------------------------------------------------------------------|
| 1    | Paper roll from many supplier              | Check samples of the material before it is received and inspect the material before use |
| 2    | The extruder need time to be stable        | During the first 1 minute when the machine is running, set the machine at a slow speed, so that the extruder and paper rates are in line |
| 3    | The machine is old                         | Replace the machine components according to the latest standards                      |
| 4    | Tucked pieces of paper                    | Pay attention to the cleanliness of the blade bearings along with the cutting unit and carry out regular checks and changes |
| 5    | Unoptimal Material Handling                | Provides cover for resin glue and potato starch glue, as not to be exposed to outside air |
Table 5. High reject of printing proposed improvement

| Rank | Failure Mode                          | Proposed Improvement                                                                 |
|------|--------------------------------------|---------------------------------------------------------------------------------------|
| 1.   | Unoptimal Material Handling           | Provides cover for ink, as not to be exposed to outside air                             |
| 2.   | Tucked pieces of paper                | Pay attention to the cleanliness of the blade bearings for the cutting unit and carry out regular checking and replacement |
| 3.   | Tucked pieces of paper in printing unit | Make sure the printing unit is clean and there are no extra materials, especially on the stamp. |
| 4.   | Ink from many supplier                | Check samples of the material before it is received and inspect the material before use. |

4. Conclusion

Based on the research objectives to be achieved, the conclusions obtained from the results of the research are the DPMO value obtained from the production process on tubing machines equal to 3691. The achievement of sigma value is 4.18. Even though the achievement of the sigma value is above average, there must always be continuous improvement to achieve the Six Sigma target. From this research, types of defects that often occur in tubing machines are gluing, printing, mismatched sizes, and paper Extention. Proposed improvements for gluing problems include check samples of the material before it is received and inspect the material before use, set the machine at a slow speed for the first minute, so that the extruder and paper rates are in line, replace the machine components according to the latest standards, pay attention to the cleanliness of the blade bearings along with the cutting unit and carry out regular checks and changes and provide cover for resin glue and potato starch glue, as not to be exposed to outside air. Proposed improvements to the printing problem are provide cover for ink, as not to be exposed to outside air, pay attention to the cleanliness of the blade bearings for the cutting unit and carry out regular checking and replacement, make sure the printing unit is clean and there are no extra materials (especially on the stamp) and check samples of the material before it is received and inspect the material before use. For further research, it would be better to continue this research so that the control stage in the DMAIC stage is complete by implementation of the proposed improvement given then conduct an evaluation and comparison with the previous conditions. In addition, research can also be added regarding the cost aspects that have not been discussed in this study.

5. References

[1] Brue G 2005 Six Sigma for Managers: 24 Lesson to Understand and Apply Six Sigma Principles in Any Organization (New York: McGraw-Hill Education)
[2] Stamatis D H 2004 Six Sigma Fundamentals: A Complete Guide to The System, Method, and Tools (New York: Production Press)
[3] Mitra A 2016 Fundamentals of Quality Control and Improvement (New Jersey: John Willey and Sons Inc.)
[4] Ma’arif M S, Tanjung H 2003 Manajemen Operasi (Jakarta: PT GramediaWidiasarana)
[5] Nasution S R, Respati D 2011 Perbaikan kualitas dengan metode PDCA untuk Mengurangi Cacat Produk Frame Actuator pada Proses Frame Assembly di PT SCJI. FTUP Engineering Journal XXIV(2), 69 – 77
[6] Martins A C A, Leite J C, Parente R S, Mustafa E V, Dinolal C S, Santos A D J D 2019 Method of Problem Analysis and Solving applied to Quality and Productivity in a Furniture Industry. International Journal of Advanced Engineering Research and Science (IJAERS) 6, 587-610