Quality Control of Frame Production Using DMAIC Method in Plastic PP Corrugated Box Manufacturer

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Abstract. Corrugated carton boxes as a storage for products is common use in industry nowadays, corrugated carton box has many advantages, hardiness, air resistance, more neat and strong. To produce this corrugated box, it needed a frame to support the edge of the carton to make it stronger. This study was conducted at one of the pp corrugated manufacturers in Indonesia. The company oftenly receive complaints caused of quality problems of the frame. Research aimed to provide quality improvement using DMAIC (defining-measuring-analyzing-improving-control) as analysis method. The results of study concluded that the causes of defect consist of several factors, human factors, poorly trained of machine operators. The second cause is the engine factor, the barrel screw used has an incorrect temperature and rotation speed of the screw is inappropriate. The third cause is the material factor, dirty materials that was entered the machine affected the size of materials produced. Improvements carried out using design of experiment and standard operation procedures.

1. Introduction
These One thing that cannot be separated from the system of buying and selling is shipping goods. Where the delivery of goods requires a package that can protect the goods in order to remain in a safe condition up to the hands of the customer. The growing packaging industry in Indonesia is packaging made from raw materials in the form of paper and cardboard, plastic, metal and glass. Paper and cardboard packaging took first place at 40%, 34% plastic packaging, 14% metal packaging and 11% glass packaging. Cardboard packaging has been produced in the form of boxes for various products, but the use of cardboard has constraints, the disadvantage is that the box is made of paper so it is not waterproof, cannot withstand heavy loads and cannot be used repeatedly because the cardboard is easily damage [8]. Cardboard has several drawbacks, so packaging is made to resemble cardboard from non-paper plastic material called pp corrugated. PP corrugated (KKG) has the same shape as cardboard with only different types of material. KKG is stronger, waterproof, and can be used repeatedly because it is easily decomposed so it does not damage the environment [7]. To be used as a shipping box, KKG is cut, shaped, glued together to form a box called a KKG. To support the strength of the KKG, a part called frame is needed. This part is in the form of a long black list clamp that is used at the edges of the KKG to add strength and keep the KKG from being damaged quickly. The company produces frames used in KKG. The quality of the frames produced is very instrumental in supporting the quality of the KKG. The frame is otherwise qualified if it has a size that fits the KKG size. The company got a number of complaints related to the frame that was sent did not match the size of the KKG and could not be assembled because it was loose and had legs that were too long. To ensure the quality of the frames produced, quality testing is carried out in the frame production process. Testing process is done by taking a sample of 1 stick per 1 hour for 6 working days with a total sample of 42 stick
The measurement of the frame is done in 3 parts namely the upper component, the left leg and the right leg. The value of \( Cp > 1.33 \) then the process is very good, if \( 1.00 < Cp < 1.33 \) then the capability process is good and if the value of \( Cp < 1.00 \) then the process capability is low [9]. The calculation results show the \( Cp \) value of the upper component is 2.87, the right leg is 0.47 and the left leg is 0.46, the results of this measurement show the results of \( Cp \) is below 1.33.

2. Quality Control and Six Sigma
Quality control is the use of techniques and activities to achieve, maintain, and improve the service quality of products [1]. Service or product with good quality are services or products that meet consumer expectations [14]. The quality has a correlation with purchase intention [13], purchase decision [12][2], customer satisfaction [4][17] and customers' trust [3][11]. Quality improvement can be beneficial for building networks in product marketing [7]. Control is an activity carried out to ensure that the production and operations carried out in accordance with what is planned and if deviations occur, then these deviations can be immediately addressed [15]. There are several factors that influence quality control, namely process capability, applicable specifications, acceptable level of non-compliance and quality costs [10]. Six Sigma has the advantage of combining the strengths of human resources and the power of processes [6]. Sigma which is a unit of Standard Deviation which is also symbolized by the symbol \( \sigma \) or \( 6\sigma \). Six Sigma is also often used as an indicator to see the performance of the company, the higher of sigma means the better of quality performance [18]. Performance of the organization will determine how competitive its organization [19][20], and quality of product is one factor that influence performance of organization. Six Sigma can be considered as one of the most important developments for quality management and quality improvement processes [14]. Financial evidence shows that Six Sigma helps improve managerial performance [5]. Sigma as a management philosophy that focuses on reducing errors, waste and rework [6].

3. Research Methodology
The study was conducted to control the quality of frame products in the extruder division at one of the pp corrugated manufacturers in Cikarang, Indonesia. Data collection was carried out in 2020. The study began with a preliminary study and found disability data on frame size uniformity, then conducted a literature study. To prove the existence of defects in the frame, researchers collected data in the form of sample size of frames and customer data that provided complaints. Analysis using DMAIC, the Define phase begins by determining CTQ and making a SIPOC diagram. The measure phase starts with measuring the value of sigma, making a control chart and measuring process capability. The Analyze phase discusses the process of identifying the causative factors. The improve phase use design experiments and standard operation procedure for control the process.

4. Discussion and Analysis
Data collection is categorized in the size of the left and right legs of the 5mm frame. Based on sample data then data processing is performed. In the discussion at the define stage, it is known the production process flow and quality standards of the frame. Table 1 shows a SIPOC diagram of the 5 mm frame production process with a length of 2 m.
Table 1. SIPOC Diagram of Frame Process Production

| Supplier  | Input                        | Process                                      | Output                                | Customer                  |
|-----------|------------------------------|----------------------------------------------|---------------------------------------|---------------------------|
| SSM Inc.  | Plastic seeds (ABS type)     | 1. The material is heated for 4 hours        | 2 meters long frame that has          | Packing and warehouse     |
| TB, Inc.  | that have been sifted        | 2. Material is entered the extruder machine  | been tied 10 stems/bunch              | division. The frame is    |
| MS, Inc.  | and controlled by material   | 3. Melting process                           |                                       | ready to send             |
|           |                              | 4. Cooling process                           |                                       |                           |
|           |                              | 5. Once formed, the frame is pulled by roller machine |                                       |                           |
|           |                              | 6. Measurement and cutting process           |                                       |                           |

Critical To Quality (CTQ) - There is a guideline for producing good quality frames. The frame consists of the left leg, top, and right leg where each size is + - 0.5 mm. Figure 1 shows the frame size. Table 2 shows the CTQ details of the frame. CTQ is determined by the company which refers to the size of the elbows and pp cartons, in order to produce a good quality of frame, then the frame size must not too narrow.

Table 2. CTQ of Frame

| Components | Size  | USL  | LSL  |
|------------|-------|------|------|
| Left leg   | 26 mm | 26.5 mm | 25.5 mm |
| Right leg  | 23 mm | 23.5 mm | 22.5 mm |

Based on the observations, the sigma value of the frame production can be calculated, the number of units (U) of frame products produced is 19520 sticks. Opportunities (OP) for frame quality are 3 characteristics, namely the size of the left and right leg and the size of the upper frame. Defect (D) of production is 1000 units. Defect Per Unit (DPU) by dividing D by U, obtained DPU is 0.0383. Total Opportunities (TOP) obtained by multiplication U and OP is 58560. Defect per Opportunities (DPO) is obtained by dividing D and TOP is 0.013. Defect per Million Opportunities (DPMO) is obtained by multiplication of DPO and one million is 12756.148. The Sigma level obtained is 3.73.

Figure 1. Process Capability

The results of the calculation of process capability show a Cp value of left leg is 0.52 and 0.50 for right leg, which means the production process has not been able to produce a quality product.
Table 3. FMEA Analysis

| Object          | Process            | Potential Failure Mode       | Result                                         | RPN  |
|-----------------|--------------------|------------------------------|-----------------------------------------------|------|
| Man             | Operator           | The operator is lack of skilled | Escaped frame that does not fit the size      | 112  |
| Machine         | Melting Process    | Screw speed                  | Material quantity is not standard             | 60   |
| Machine         | Machine Speed      | Roll machine spins too fast  | The roll machine is too fast                  | 32   |
| Machine         | Melting Process    | Temperature of screw barrel  | Unstable exit material                        | 64   |
| Material        | Preparing Process of Material | Material is dirty and late to entry | Unstable exit material                        | 48   |

Table 3 show the factors that must be resolved first are human factors, which have the highest RPN value of 112, followed by the temperature with RPN 64, the third is the speed of the screw with the value of RPN 60, the fourth is the dirty material factor with RPN value 48 and finally is a roll machine factor with a RPN value of 32. The company should make improvements in all factors that affect but if there are any considerations in terms of time, cost and RPN, improvement can be done at least 80% of the defects caused by these factors including improve human factors, namely operators, improve machine factors, namely speed of screw machine, temperature and material factors.

In the engine factor, the cause of the discrepancy in frame size is inaccurate screw barrel temperature, roll speed, and screw speed. To be able to make improvements, used ANOVA by conducting experiments of temperature, roll machine speed, and screw speed where the right settings will be found in experiments conducted. Anova temperature testing is done with 3 temperatures namely 130°, 150° and 170°, testing is applied 20 times for the left leg and right leg. ANOVA statistical test is used to validate the relationship of the temperature of the screw with the size of the left leg of the frame. The one way ANOVA calculation results show the p-value generated is 0.000 because the p-value is greater than alpha (α> 0.5) then the conclusion of anova is reject Ho and states that the screw temperature has a relationship with CTQ. Based on experimental data, the optimal temperature is 150°. The next factor that will be carried out by the experiment is screw speed with 3 treatments 24, 25 and 26 rpm. Based on experimental data, the optimal temperature is 25 rpm because at that temperature the size of the left and right leg of the frame meets the criteria of CTQ. In addition to the screw barrel temperature and screw speed factors, experiments were carried out on the speed of the roll machine with 3 treatments 16, 16.5 and 17 rpm. The optimal speed is 16 rpm.

5. Conclusion
According to DPMO calculations, frame production has a sigma value of 3.72, the process capability of frame production produces Cp of 0.52 for the left side and 0.50 for the right side. The causes of frame defects are human factors, which are less skilled operators, machine factors, namely temperatur screw barrel, screw speed and roll speed. Another cause of disability is dirty material. To improve these factors a design experiment was carried out which produced a good screw barrel temperature of 150°, the optimal screw speed was 25 rpm and a roll engine speed of 16 rpm. Supervision is carried out by creating a Standard Operation Procedure (SOP) where every staff involved in the frame production process can be managed and worked according to the system. Some suggestions are conducting training, briefing, providing motivation and providing an understanding of the importance and quality responsibilities of each staff involved. Perform improvements in screw speed, screw temperature, and roll speed. Make improvements to the material also so that the material will be processed better. Design and socialize SOP, so that every worker works according to the system. Documenting the results of production, total disability and problems that arise during the production process.

References

[1] Besterfield, D. H. “Quality Control”, Pearson Education, USA, 2009.
[2] Dapas, C. C., Sitorus, T., Purwanto, E. and Ihalauw, JJOI. “The Effect of Service Quality and Website Quality of Zalora.com on Purchase Decision as Mediated by Purchase Intention”, Quality Access to Success, vol. 20, no. 169, pp. 87-92, 2019.
[3] Handi, H., Hendratono, T., Purwanto, E. and Ihalauw, J. J. “The effect of e-WOM and perceived value on the purchase decision of foods by using the go-food application as mediated by trust”, Quality Innovation Prosperity, vol. 22, no. 2, pp. 112-127, 2018.
[4] Jauw, A. L. J. and Purwanto, E. “Moderation effects of cultural dimensions on the relationship between e-service quality and satisfaction with online purchase”, Quality Access to Success, vol. 18, no. 157, pp. 55-60, 2017.
[5] Jirasukprasert, P., Reyes, G. A., Kumar, V. and Lim, K. M. “A six sigma and DMAIC application for the reduction of defects in a rubber gloves manufacturing process”, International Journal of Lean Six Sigma, vol. 5, no. 1, pp. 2-21, 2014.
[6] Nurprihatin, F., Jayadi, E. L. and Tannady, H. “Comparing Heuristic Methods’ Performance For Pure Flow Shop Scheduling Under Certain And Uncertain Demand”, Management and Production Engineering Review, vol. 11, no. 2, pp. 50-61, 2020.
[7] Karno, C. G. and Purwanto, E. “The effect of cooperation and innovation on business performance”, Quality Access to Success, vol. 18, no. 158, pp. 123-126, 2017.
[8] Kirwan, M. J., Coles, R. and McDowell, D. “Food packaging technology”, Blackwell, UK, 2003.
[9] Klimchuk, M. R. and Krasovec, S. A. “Packaging design: Successful product branding from concept to shelf”, John Wiley & Sons, New Jersey, 2006.
[10] Montgomery, D. C. “Introduction to Statistical Quality Control”, John Wiley & Sons, USA, 2009.
[11] Pitaloka, E. and Tannady, H. “Analysis of citizen satisfaction on National Agency of Drug and Food Control of Republic Indonesia (NADFC)”, Technology Reports of Kansai University, vol. 62, no. 3, pp. 1069-1075, 2020.
[12] Purwanto, E. “The effect of consumer ethnocentrism on perceived domestic product quality and purchase intentions among young consumers in Jakarta, Indonesia”, International Journal of Asian Social Science, vol 4, no. 9, pp. 1003-1012, 2014.
[13] Purwanto, E. “The Effect of Cosmopolitanism on Perceived Foreign Product and Purchase Intentions: Indonesia Case”, Quality Access to Success, vol. 17, no. 155, pp. 94-98, 2016.
[14] Tannady, H. and Maimury, Y. “Increasing the Efficiency and Productivity in the Production of Low Voltage Switchboard Using Resource Constrained Project Scheduling”, Journal of Industrial Engineering and Management (JIEM), vol. 11, no. 01, pp. 01-33, 2017.
[15] Slavoljub, S., Srdjan, S. and Predrag, V. “Management control in modern organizations”, International Review, vol. 3-4, pp. 39-49, 2015.
[16] Sutiono, Hendratono, T. and Purwanto, E. “Identification of Factors Influencing Physician Prescription Loyalty”, International Journal of Scientific & Technology Research, vol. 8, no. 9.
[17] Tannady, H., Nurprihatin, F. and Hartono, H. “Service quality analysis of two of the largest retail chains with minimart concept in Indonesia”, Business: Theory and Practice, vol. 19, pp. 177-185, 2018.
[18] Tannady, H., Gunawan, E., Nurprihatin, F. and Wilujeng, F. R. “Process improvement to reduce waste in the biggest instant noodle manufacturing company in south east asia”, Journal of Applied Engineering Science, vol. 17, no. 2, pp. 203-212, 2019.
[19] Tannady, H., Gunawan, F. E. and Heryjanto, A. “Moderation Effect Of Work Motivation Toward Employee Engagement Of Worker In Textile Industry In Province Of Central Java, Indonesia”, Test Engineering and Management, vol. 83, pp. 9716-9723, 2020.
[20] Tannady, H., Tannady, H., Ismuhadjar. and Zami, A. “The Effect of Organizational Culture and Employee Engagement on Job Performance of Healthcare Industry in Province of Jakarta, Indonesia”, Quality: Access to Success, vol. 20, no. 169, pp. 18-22, 2019.