Quality Improvement of Corrugating Medium Paper Using Six Sigma in Paper Manufacturing Company

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ABSTRACT

Paper Company (PC, is a nickname) is a company which produces brown paper, mainly test liner and medium corrugating paper 10.000 MT/month and integrated with paper board company. The production process in the paper industry is continuing process. The quality report in paper mill unit 2 has a defect over the percentage that exceeds company standards. The lowest percentage of defects is in September 2021, which is 2.94%, while the company's target is 1%. DPMO is 45.600 it is equal with 3,35 sigma. To achieve this target, research was carried out to improve the quality of PM 2 papers using the six sigma method. Six sigma begins with the DMAIC stage (Define, Measure, Analyze, Improve, and Control). Define stage by making a flow diagram of the production process by making a SIPOC diagram. Measure stage, quality identification is carried out by describing the analysis of the data and measuring the work baseline. The analysis stage will be a capability analysis and finding the root of the problem using an Ishikawa diagram. The improvement stage, which contains proposed improvements, and the control stage will be carried out by comparing the results before and after the improvement. Based on the analysis, the analysis obtained three recommendations for improvement: making SOP for setting basic weight, refresh SOP for checking and sampling basic weight, and modification headboxes in the QCS system Result has been taken in January week 3, the DPMO is 25.566 it is equal to 3,68 sigma.

Keywords: quality improvement, six sigma, DMAIC, and Ishikawa diagram

1. INTRODUCTION

Quality control in the manufacturing industry is very important. Quality control can be carried out by determining incoming raw material standards, incoming supporting material standards, production process standards, and finished goods standards. Standards of finished goods that are set must meet the standards of customer desires. Finished goods whose quality is below specifications will require rework. The rework process will increase production costs which are detrimental to the company. The choice that will be chosen by the company is to carry out a rework process or sell products at special prices, where both of these options will harm the company so that quality control is important to minimize product failures, reduce production costs and increase company profits.

Inappropriate quality can be caused by several factors, namely machine, method, material, human, and environmental factors (Socovic, 2005). The machine factor is a disturbance from the

machine such as equipment damage and instrumentation disturbances from the machine which can be overcome by making a machine repair schedule. The method factor is operational standard errors such as setting point errors, so that it can be overcome by making SOPs properly and clearly. Material factors are errors in the characteristics of raw materials, auxiliary materials, and errors in the preparation of a production process. The human factor is the error in running the SOP. Environmental factors are factors in the production environment that can affect production results such as humidity in the production room, etc.

Paper Company (PC) is a paper manufacturing company that produces brown paper, cardboard boxes, and strapping bands. The paper produced is a recycle test liner and corrugating medium with a basic weight of 90 - 350gsm. PC also produces corrugated cardboard which is integrated with paper units and marketed to end user customers. Research will be conducted to improve the quality of corrugating medium paper in paper mill (PM) unit 2 because paper mill unit 2 has a production efficiency of more than 80% and this type of paper is more in demand by customers. **Table 1** describes the percentage of defect products that occurred in PM 2.

Tabel 1. Percentage defect product

Month	Defect (Ton)	% Defect
April	183,000	8,38
May	335,124	14,30
June	166,028	6,38
July	181,466	7,62
August	149,506	6,03
September	73.484	2,94

The company's target for the percentage of defect products is a maximum 1% from total production output. In April to September the company's target was not achieved so it is necessary to evaluate and improve the process to achieve the target. In this study, the six sigma method will be used to reduce process variance so that the process can be more consistent. The use of the six sigma method is a method to achieve good operating performance, which is up to 3.4 defects for one million results so that the percentage of production according to standards is 99.99996%.

2. LITERATURE REVIEW

2.1 Quality

Quality is a feature that meets customer needs, quality can provide greater customer satisfaction to increase revenue, but in real conditions improving quality requires investment and increasing costs so that quality improvements require increased costs. The word quality is defined on several criteria including product, product specification, customer, customer satisfaction, deficiency, and customer dissatisfaction. Products are generally defined as goods produced. Product specifications are the criteria for a product that will meet with customers. Customer dissatisfaction is a situation where a product error/defect is considered disturbing so that claims, complaints, and so on (Juran, 1999) (Chen, 2016).

2.2 Six Sigma

Six sigma is a quality improvement method that aims to reduce defective products to 3.4 DPMO (defects per million opportunity) by using a normal distribution and a strong relationship between defective products, production yield, reliability, cycle time, etc. (Socovic, 2005) There are 2 perspectives on six sigma are statistical and methodological perspectives.

- Statistical perspectives
  Sigma is the standard deviation or deviation from mean. A process is said to be good if it is still in the range of the upper and lower limits of the deviation, while the value outside the deviation can be declared as a defect. **Tabel 2** is the colleration between defect per million opportunity (DPMO) with sigma (Wijaya, 2010).

Tabel 2. Colleration DPMO and Sigma

Sigma Score	DPMO	%Good
0	933,193	0,067
1	691,462	30,85
2	308,538	69,15
3	66,807	93,32
4	6,210	99,38
5	233	99,98
6	3,4	99,9997

Defect per unit (DPU):
DPU = Total defect product
DPU = Total Defect Product / Total Production Result (1)
Defect per million opportunities (DPMO)
DPMO = DPU × 1.000.000 / Defect Probability (2)

- Methodological Perspectives
  Six sigma is a strategy implemented by all members of the company in accordance with the company's vision and mission which aims to increase productivity and fulfill customer desires thereby increasing company value. There are five stages in implementing the six sigma strategy, namely Define-Measure-Analyze-Improvement-Control (DMAIC). DMAIC is the key to six sigma analysis to achieve customer satisfaction by minimizing product defects (Mehrjerdi, 2011).
  - Define is the main problem to be discussed (Critical to Quality)
  - Measure is a phase to measure the current situation by collecting data and identifying problems
  - Analyze is a phase to identify the root of the problem
  - Improvement is a phase to implement solutions to solve problems that have been identified in the analyze phase
  - Control is the phase of evaluating the improvement carried out whether it is appropriate or not, if it is not appropriate, it is necessary to repeat the cycle

2.3 Root Cause Analysis (RCA)

Root Cause Analysis is a method of solving problems by identifying a problem to the root of the problem. Factor is the root of the problem if when the factor is removed it can reduce or prevent failure. RCA is often used to analyze a problem. Making a good RCA is a systematic RCA that starts from identification to conclusions accompanied by evidence. In the manufacturing process, causal relationships and 5 whys can be used. Ishikawa developed the process of making a cause-effect diagram with the following stages (Montogmery, 2003):

1. Determine a problem to be analyzed
2. Draw arrows from left to right and place the problem on the right arrow and become the main arrow
3. Determine the possible cause and place it with another arrow and connect it to the main arrow
4. Determine other causes that may occur as a branch of step number 3

3. METHODS

The data is taken based on the company's internal data and data from interviews in the company. The data that has been collected then be processed and analyzed using DMAIC method.

3.1 Define

The process flow mapping is taken from the 125 gsm corrugating medium paper production diagram from a documented process flow chart. The process flow chart is detailed to support the improvement phase. Determination of the focus improvement is carried out to improve quality and reduce the number of products that are not up to standard. The determination is taken based on the most frequent defects.

3.2 Measure

The focus of improvement is taken from the list of the highest percentage of defective items that need improvement. From the percentage of product defects then made a Pareto diagram. The measurement of the work baseline uses the six sigma method with the unit of measurement for DPMO (Defect Per Million Opportunity) and also the level of sigma capability for conditions prior to improvement.

3.3 Analyze

Capability analysis is carried out to find out whether the current process is able to meet the required standards. The RCA analysis was made ishikawa diagram to find the root cause of the product defect. The results of the analysis are found the most basic factors that can lead to defective products.

3.4 Improvement

Improvements are made to reduce the number of items that are not up to standard by making suggestions for improvement according to the root cause of each type of defect so that it reaches the desired sigma value.

4. RESULTS

4.1 Define

Define is the initial stage of DMAIC which contains a description of the paper production process using supplier, input, process, output, and customer (SIPOC) diagrams and is carried out to find out the number of defective products per month in 2021. **Tabel 3** is production data in Agust and September 2021

Table 3. Production Data in August and September

Month	Total Production (Roll)	Defect (Roll)
August	1478	83
September	1568	56

From **Table 3** the defect that occurs exceeds the company's standard where the company's standard is a maximum of 1%. The defects that occur are non-standard basic weight, excessive cobb size, non-standard moisture, less neat paper cuts, more joints, uneven basic weight, and loose rolls. SIPOC diagram shows the activities of corrugating medium paper production starting from the supply of raw and auxiliary goods that are processed into products that will be sold to customers. The SIPOC diagram was created by conducting interviews with various parties from PPIC and production. Here is a SIPOC diagram in **Figure 1**.

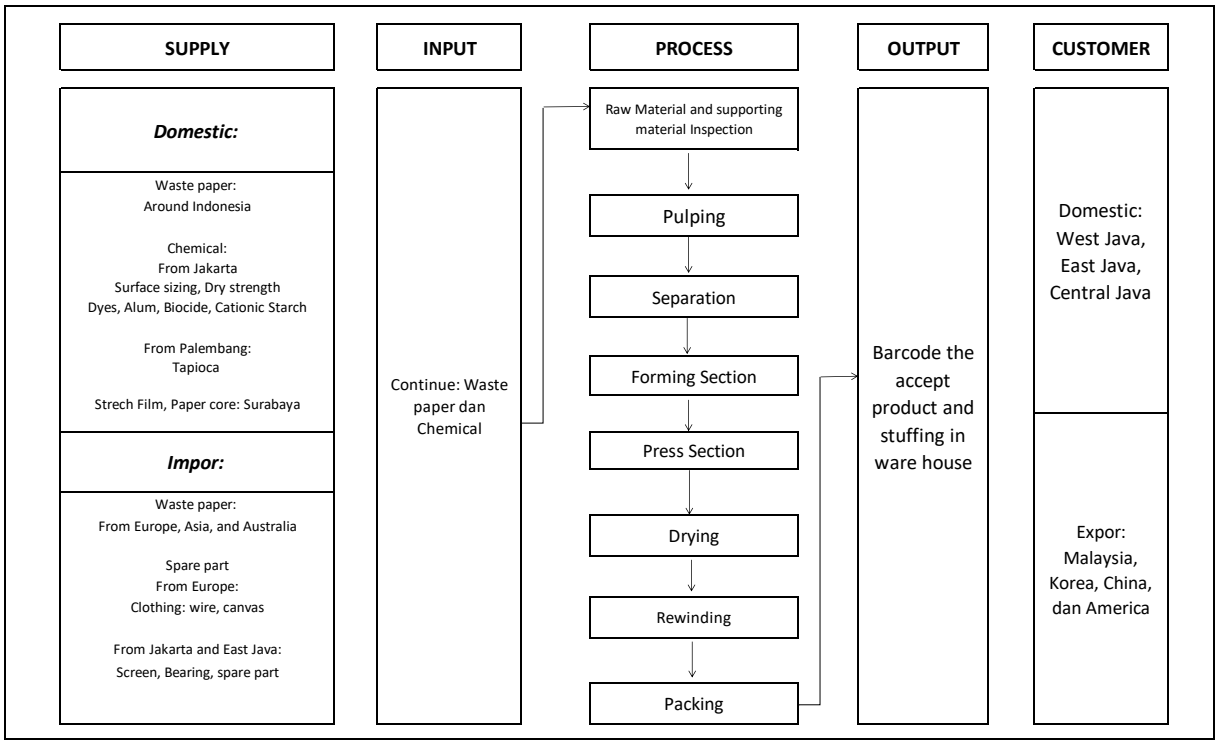

Figure 1. SIPOC Diagram

4.2 Measure

At the measure stage is an advanced stage which aims to perform data processing. The steps are taken to determine the critical to quality and making control maps. At this stage, identification of defects that occur in August and September 2021 is carried out in pareto diagram **figure 2** and the calculation in **tabel 4**. Using equation 1 and 2 the result of DPMO is 45,600 it is equal with 3.35 sigma.

Tabel 4. Calculation for Pareto Diagram

Defect	**Quantity**	**Persentage**	**Accumulation**
Unstable Basic Weight (BTS)	47	33.8%	33.8%
Over cobb size (CBL)	39	28.1%	61.9%
Over moisture (MTS)	24	17.3%	79.1%
Over joint (SLB)	12	8.6%	87.8%
Uneat cutting (PKR)	11	7.9%	95.7%
Under Hardness Standard (GBS)	6	4.3%	100%
Total	**139**	**100%**	

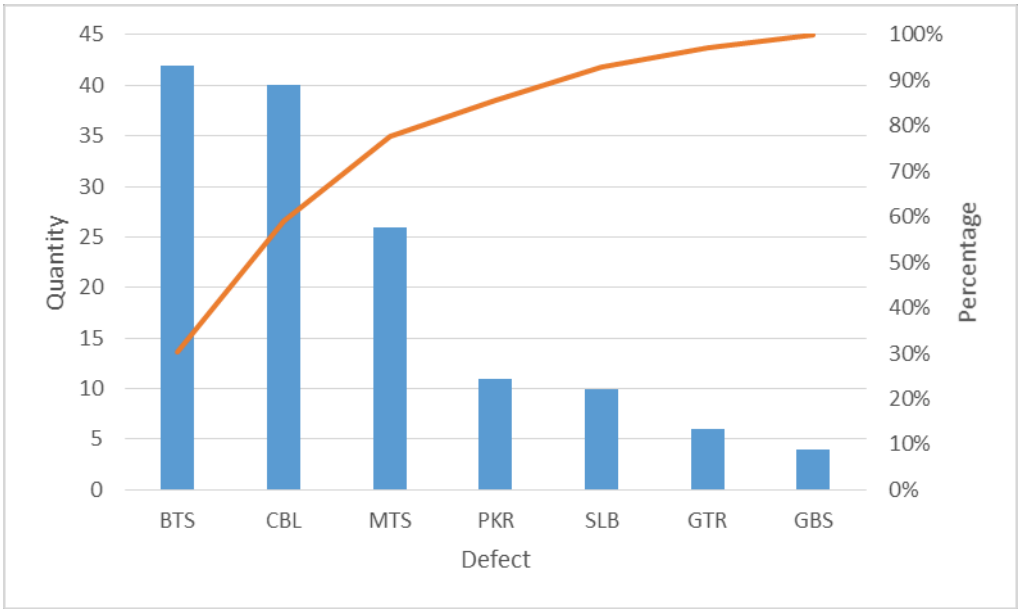

Figure 2. Pareto Diagram of Product Defect

4.3 Analyze

Improvement is focussed in unstable basic weight. Factors causing defects are made by brainstorming and interviews with the production department. The results of the brainstorming and interviews are depicted on a ishikawa diagram in **Figure 3.**

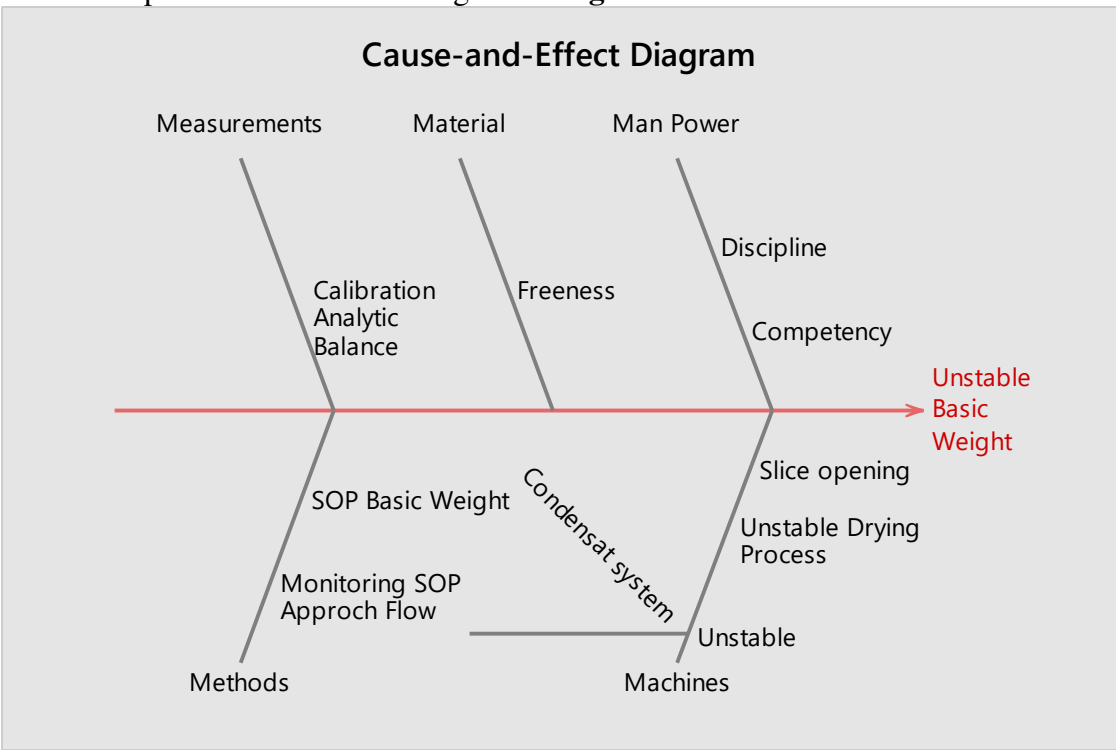

Figure 3. Ishikawa Diagram

The root factor is SOP in monitoring approach flow, instal DCS system, and calibrate the analitic balance.

4.4 Improve

At the end of 2021, a quality improvement program is refresh SOP in approach flow, calibrate analitic balance and instal DCS. The SOP refresh trial in December 2021 was carried out on one operator team. The SOP refresh was carried out by updating the SOP and applying punishment. There are 2 hypotheses:

H0 = there is no difference in work results after SOP refresh

H1 = there is a difference in work results after refreshing the SOP

Data is used in December the 3rd week with the same operator team taken on 6 working days. **Table 4** is the result of comparison before and after SOP refresh.

Tabel 5. Result of Refresh SOP

Before Refresh SOP	After Refresh SOP
5	0
2	3
3	1
1	0
2	0
2	2

Using t-test hypothesis in minitab 17 the result is:

	N	Mean	StDev	SE Mean
Before training	6	3,17	1,47	0,60
After training	6	1,00	1,26	0,52

Difference = μ (before training) - μ (after training)
Estimate for difference: 2,167
95% CI for difference: (0,374; 3,959)
T-Test of difference = 0 (vs ≠): T-Value = 2,73 P-Value = 0,023 DF = 9

p-value = 0.023 with p-value less than 0.05 then H0 is rejected and H1 is accepted. It can be concluded that there are differences in work results after the SOP refresh is carried out. In January 2022 the improvements that have been made are to refresh the SOP in all team member.

4.5 Control

Result has been taken in January week 3, the DPMO is 25,566 it is equal to 3.68 sigma. The improvement was made correctly.

5. CONCLUSIONS

The critical factor in quality is unstable basic weight, over moisture content, and over cobb size. The root factor is SOP in monitoring approach flow and there is no DCS system. improvement can be done by refreshing the SOP and procuring the DCS system so that the system can be monitored in real time and reduce the human error factor. Refresh SOP to dicipline operator has been done in January week 1, the result is the DPMO is decreasing from 45,600 to 25,566 dan sigma is increasing from 3.35 to 3.68.

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