The Implementation of FTA (Fault Tree Analysis) and FMEA (Failure Mode And Effect Analysis) Methods to Improve the Quality of Jumbo Roll Products

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Abstract. PT IKPP is a manufacturing company engaged in the field of integrated pulp and paper industry with foreign investment status (PMA). Based on data obtained from September 2016 until February 2017 PT. IKPP has quality related issues on Jumbo Roll products. The product during September 2016 until February 2017, it was found defect of 1,162 (27%) of the total production of 4,346 (100%). The types of defects that occur in Jumbo Roll products are Thickness, Tensile Strength, Smoothness, Cobb Value, Porosity, Base Weight, Water Resistance, and so forth. Based on the results of analysis performed using pareto chart found 9 defects, then 3 of 9 defects with the total cumulative percentage is in the number 80%, which is the thickness of 51.89%, Tensile Strength of 25.90%, and Smoothness of 14.29%, so the main improvement focused on all three types of defects. Based on analysis of FTA method (Fault Tree Analyze) found cause of problem of defect Thickness, Tensile Strength, and Smoothness, that is influenced by some factor that is man, machine, and material. The proposed improvements that can be made for improvements in Thickness, Tensile Strength, and Smoothness are based on the largest RPN (Risk Priority Number) from the analysis of FMEA (Failure Mode and Effect Analysis) is the improvement of Thickness by performing regular maintenance on the refiner parts such as knives and refiner motor, Tensile Strength repair by setting for pulp composition (NBKP) in accordance with standard pulp composition (NBKP) on each type of paper, and improving Smoothness by setting the amperes on the refiner to match the ampere that has been set in accordance with the standard ampere on the type of paper.

Keywords: Quality, Jumbo Roll, FMEA, FTA

1. Introduction
PT. IKPP is a manufacturing company engaged in the field of integrated pulp and paper industry with the status of Foreign Investment (PMA). The factory is spread over 3 locations in Indonesia, namely pulp and paper processing factory located in Perawang, Riau, a paper mill in Tangerang, and a paper packaging factory in Serang, Banten. The business network includes several businesses or types of activities, including pulp making, cultural papers consisting of paper for written and printed purposes.
(layered and uncoated), photocopy paper, and industrial paper consisting of packaging paper including Containerboard (Linerboard and Corrugating Medium), Corrugated Shipping (Convertible from Containerboard), Boxboard and colored paper. The products made by this company not only meet the domestic market, but have penetrated the international market. The company has exported to countries in Asia, North and South America, Australia, Africa, and also Europe.

Based on data obtained during September 2016 to February 2017 at present PT. Indah Kiat Pulp & Paper, TbK has quality related problem that is on Jumbo Roll product. It was found on the product, during September 2016 to February 2017, a defect of 1,162 (27%) of total production of 4,346 (100%) Jumbo Roll. The types of defects that occur in Jumbo Roll products are Thickness, Tensile Strength, Smoothness, Cobb Value, Porosity, Base Weight, Water Resistance, and so forth. Therefore, in this defect problem needs to be done an improvement with the aim to optimize the quality of the Jumbo Roll product.

There are several quality control methods that can be used to reduce defective products. One of the methods that can be used is FMEA (Failure Mode and Effect Analysis) and FTA (Fault Tree Analysis). FMEA (Failure Mode and Effect Analysis) is a method used to define, identify, and eliminate defects and problems in the production process both known and potential problems occur in the system. While FTA (Fault Tree Analysis) is an analytical method that can analyze system failure, look for aspects of system involved in main failure, and find the cause of product defect in production process. For this purpose, this research is done by using FMEA (Failure Mode and Effect Analysis) method and FTA (Fault Tree Analysis).

2. Literature Review

2.1. Definition of Quality
Gasperz (2002) defines quality as customer satisfaction or conform to needs or requirements (conformance to the requirements).

2.2. Definition of FMEA (Failure Mode and Effect Analysis)
According to the stamatis in [4], FMEA is an engineering technique used to establish, identify, and to eliminate known failures, problems, errors, and the like from a system, design, process, and or service before reaching the consumer.

According to Chrysler in [5], FMEA is a structured procedure for identifying and preventing as many modes of failure as possible. FMEA is used to identify the sources and causes of a quality problem.

2.3. Variable FMEA (Failure Mode and Effect Analysis)
[6], describes the three main variable processes in FMEA (Failure Mode and Effect Analysis) ie Severity, Occurrence, and Detection. These three processes serve to determine the rating of seriousness on Potential Failure Mode. Here are 3 main variables in FMEA (Failure Mode and Effect Analysis), which are as follows:

1. Severity (Fatal)
According to [1], severity is a matter of identifying the potential impact of a failure by ranking failure in accordance with the outcome. The level of influence of failure (severity) has a ranking of 1 to 10. For the 1st rank is the lowest level of seriousness (small risk) and rank 10 is the highest level of seriousness (big risk).

There is a severity explanation of the failure mode for each ranking that can be seen in Table 1 of Severity Table.
Table 1. Severity Table

| Rating | Criteria |
|--------|----------|
| 1      | Negligible Severity. We need not think that this effect will have an impact on product quality. Consumers may not pay attention to this disability. |
| 2      | Mild Severity. As a result will be mild, consumers will not feel the decline in quality. |
| 4      | Moderate Severity. Consumers will feel the decline in quality, but still within the limits of tolerance. |
| 7      | High Severity. Consumers will feel the decline in quality that is beyond the tolerance limit. |
| 9      | Potential Severity. The resulting effect is very influential on other quality, consumers will not accept it. |

Source: Gasperz (2002)

2. Occurrence
According to [1], occurrence is a possibility that the cause may occur and result in a form of failure during the life of the product. Explanation of frequency of failure (occurrence) for each ranking can be seen in Table 2 Occurrence Table.

Table 2. Occurrence

| Degree    | Based on the Event Frequency | Rating |
|-----------|------------------------------|--------|
| Remote    |                              |        |
| L         | 0.001 per 1000 item          | 1      |
| o         | 0.1 per 1000 item            | 2      |
|           | 0.5 per 1000 item            | 3      |
| Moderate  |                              |        |
|           | 1 per 1000 item              | 4      |
|           | 2 per 1000 item              | 5      |
|           | 5 per 1000 item              | 6      |
| High      |                              |        |
|           | 10 per 1000 item             | 7      |
|           | 20 per 1000 item             | 8      |
| Very High |                              |        |
|           | 50 per 1000 item             | 9      |
|           | 100 per 1000 item            | 10     |

Source: Gasperz (2002)

3. Detection (Findings).
According to [1], detection is a way (procedure), test, or analysis to prevent failure of the service, process, or customer. There is a detection rate assessment which can be seen in Table 3 of the Detection Table.
Table 3. Detection Table

| Rating | Criteria | Based on the Event Frequency |
|--------|----------|------------------------------|
| 1      | Preventive methods are very effective. No chance of cause may arise. | 0.001 per 1000 item |
| 2      | Possible causes are very low. | 0.1 per 1000 item |
| 3      | Possible causes of occurrence are moderate. | 0.5 per 1000 item |
| 4      | Prevention methods sometimes they may be the cause. | 1 per 1000 item |
| 5      | Prevention methods sometimes they may be the cause. | 2 per 1000 item |
| 6      | Prevention methods sometimes they may be the cause. | 5 per 1000 item |
| 7      | The probable cause is still high. Prevention methods are less effective. The cause is still recurring. | 10 per 1000 item |
| 8      | The probable cause is still high. Prevention methods are less effective. The cause is still recurring. | 20 per 1000 item |
| 9      | The possibility of a cause is very high. | 50 per 1000 item |
| 10     | Prevention methods are not effective. | 100 per 1000 item |

Source: Gasperz (2002)

2.4. RPN (Risk Priority Number)
According to [1], the RPN (Risk Priority Number) or the risk priority number is a mathematical product of the seriousness of the effects (severity), the probability of a cause will result in a failure associated with the effects (occurrence), and the ability to detect failure before it occurs customer (detection).

2.5. FTA (Fault Tree Analysis)
According to [3], the FTA (Fault Tree Analysis) method is as a technique of analysis, environmental analysis, and operation to find the path / solution of emerging problems. FTA (Fault Tree Analysis) is a graphical model of parallel variations and a combination of errors that arise as a result of defining existing problems.

According to [3], FTA (Fault Tree Analysis) has special symbols in its manufacture. The symbols and their meanings can be seen in Table 4 Symbols In the following FTA (Fault Tree Analysis):

Table 4. Symbols In FTA (Fault Tree Analysis)

| Simbol | Basic Event |
|--------|-------------|
|        | Basic of Error initiation that does not need further Development |
|        | Conditioning Event |
|        | Specified Condition that could be implemented to various Logic gates |
|        | Undevelopment Event |
|        | Event that can no longer be developed due to the unavailability of Information |
|        | External Event |
|        | Event that is expected to be existed |
|        | AND GATE |
|        | Error exists due to All Problems input taken place |
|        | OR GATE |
|        | Error exists due to one of the problem inputs took place |

Source: Kartika et al (2016)
There are two gates in the making of FTA (Fault Tree Analysis) ie gate "AND" and gate "OR". OR gate is used to indicate that an output event will appear if one or more input events appear. There are several input events on the OR gate. Figure 1 shows two input events on the OR gate that are input events A and B and output Q. Output Q occurs when input A occurs or input B occurs or both occur.

![Figure 1: OR Gate](source)

AND gate is used to indicate that the output will appear if all inputs occur. It is possible that some inputs occur at the AND gate. Figure 2 shows two events A and B events, and the output of event Q. Output Q will occur if both events A and B occur.

![Figure 2: AND Gate](source)

3. Research Methodology

3.1. Types of research

In this research, we use quantitative research methods because in its implementation, we involves data in the form of numbers or numbers. In accordance with its form, quantitative data can be processed or analyzed using mathematical calculation techniques. Flow Chart Research
3.2. Flow Chart of the Research

Figure 3. Flow Chart of the Research

4. Result and Discussion
4.1. Collection and Data Processing
The data collected, used in the data processing are the total production data and the overall Jumbo Roll data defect of the paper type. The data is obtained from Quality Assurance Section (QA) PT. Indah Kiat Pulp & Paper, Tbk for 6 months from September 2016 - February 2017.

The following is the data that has been collected consisting of production data and Jumbo Roll defect data of the overall type of paper.

| No | Month    | Total of Production Jumbo Roll | Total Defect Jumbo Roll |
|----|----------|--------------------------------|-------------------------|
| 1  | September| 703                            | 142                     |
| 2  | October  | 747                            | 311                     |
| 3  | November | 703                            | 156                     |
| 4  | December | 773                            | 246                     |
| 5  | January  | 763                            | 136                     |
| 6  | February | 657                            | 171                     |
|    | Total    | 4346                           | 1162                    |

Source: Quality Assurance Section PT. Indah Kiat Pulp & Paper, Tbk
The following is the Jumbo Roll defect data of all paper types occurring over a 6 month period in September 2016 - February 2017:

| No | Types of Defect     | Number of Defect (Roll) | Percentage (%) | Accumulation (%) |
|----|---------------------|-------------------------|----------------|------------------|
| 1  | Thickness           | 603                     | 51.89%         | 51.89%           |
| 2  | Tensile Strength    | 301                     | 25.90%         | 77.80%           |
| 3  | Smoothness          | 166                     | 14.29%         | 92.08%           |
| 4  | Cobb Value          | 40                      | 3.44%          | 95.52%           |
| 5  | Porosity            | 22                      | 1.89%          | 97.42%           |
| 6  | Basis Weight        | 21                      | 1.81%          | 99.23%           |
| 7  | Water Resistance    | 4                       | 0.34%          | 99.57%           |
| 8  | Surface Strength    | 4                       | 0.34%          | 99.91%           |
| 9  | Tearing Strength    | 1                       | 0.09%          | 100.00%          |
|    | Total               | 1162                    | 100.00%        |                  |

Source: Quality Assurance Section PT. Indah Kiat Pulp & Paper, Tbk

The data is then processed using the Pareto Diagram in order to find out the highest defect in the Jumbo Roll for a period of 6 months from September 2016 - February 2017, as follows:

![Figure 4 Pareto Chart](source)

Source: Quality Assurance Section PT. Indah Kiat Pulp & Paper, Tbk

Based on the principle of Pareto Chart known as 80/20 principle which means 80% due to caused by 20% cause. Thus, of the 9 defects there are 3 types of defects with a cumulative percentage total of 80% ie Thickness of 51.89%, Tensile Strength of 25.90%, and Smoothness of 14.29%, so the main improvement is focused on the three types of defects.
4.2. FTA (Fault Tree Analysis)

1. Fault Tree Analysis to Thickness

![Fault Tree Diagram for Thickness](image1)

**Figure 5.** Fault Tree Analysis to Thickness  
Source: Data Processed

2. Fault Tree Analysis to Tensile Strength

![Fault Tree Diagram for Tensile Strength](image2)

**Figure 6.** Fault Tree Analysis to Tensile Strength  
Source: Data Processed
3. Fault Tree Analysis to Smoothness

![Fault Tree Analysis to Smoothness Diagram]

**Figure 7.** Fault Tree Analysis to Smoothness
Source: Data Processed

4.3. FMEA (Failure Mode and Effect Analysis)

1. Failure Mode and Effect Analysis to Thickness

| No | Cause Of Failure Mode                                                                 | Severity Rating (S) | Occurrence Rating (O) | Detection Rating (D) | Risk Priority Number (RPN) |
|----|----------------------------------------------------------------------------------------|---------------------|-----------------------|----------------------|----------------------------|
| 1  | The Refiner section is not up to the standard                                           | 9                   | 9                     | 4                    | 324                        |
| 2  | The composition of Retention Aid is not up to the standard                              | 8                   | 8                     | 2                    | 128                        |
| 3  | The Filler Flow composition is not up to the standard                                   | 7                   | 9                     | 2                    | 126                        |
| 4  | Pulp composition (Broke) is not up to the standard                                      | 7                   | 7                     | 2                    | 98                         |
| 5  | Pulp composition is not up to standard                                                  | 7                   | 7                     | 2                    | 98                         |
| 6  | The Drying section of Paper Machine 2 is not up to the standard                         | 7                   | 7                     | 2                    | 98                         |
| 7  | Consistency in Machine Chest is not up to the standard                                  | 8                   | 6                     | 2                    | 96                         |
| 8  | High Noise Level                                                                       | 8                   | 4                     | 3                    | 96                         |
| 9  | Lack of Ventilation                                                                    | 7                   | 4                     | 3                    | 84                         |
| 10 | The Pressing section of Paper Machine 2 is not up to the standard                      | 7                   | 4                     | 3                    | 84                         |
| 11 | The Calendering section of Paper Machine 2 is not up to the standard                   | 7                   | 4                     | 3                    | 84                         |
| 12 | Fatigue                                                                               | 6                   | 4                     | 3                    | 72                         |
| 13 | Lack of Light                                                                          | 7                   | 5                     | 2                    | 70                         |
2. Failure Mode and Effect Analysis to Tensile Strength Defect

Table 8. Failure Mode and Effect Analysis to Tensile Strength Defect

| No | Cause Of Failure Mode                                      | Severity Rating (S) | Occurance Rating (O) | Detection Rating (D) | Risk Priority Number (RPN) |
|----|-----------------------------------------------------------|---------------------|----------------------|----------------------|---------------------------|
| 1  | Pulp composition (NBKP) is not up the standard           | 8                   | 7                    | 2                    | 112                       |
| 2  | The Filler Flow composition is not up to standard        | 7                   | 7                    | 2                    | 98                        |
| 3  | The Refiner section is not up to standard                | 8                   | 6                    | 2                    | 96                        |
| 4  | High Level of Noise                                     | 8                   | 4                    | 3                    | 96                        |
| 5  | Lack of Ventilation                                     | 7                   | 4                    | 3                    | 84                        |
| 6  | Fatigue                                                  | 6                   | 4                    | 3                    | 72                        |
| 7  | Pulp composition (Broke) is not up the standard         | 7                   | 5                    | 2                    | 70                        |
| 8  | Lack of Light                                            | 7                   | 5                    | 2                    | 70                        |

Source: Data Processed

3. Failure Mode and Effect Analysis to Smoothness

Table 9. Failure Mode and Effect Analysis to Smoothness

| No | Cause Of Failure Mode                                      | Severity Rating (S) | Occurance Rating (O) | Detection Rating (D) | Risk Priority Number (RPN) |
|----|-----------------------------------------------------------|---------------------|----------------------|----------------------|---------------------------|
| 1  | Bagian Refiner tidak sesuai standar                      | 8                   | 7                    | 2                    | 112                       |
| 2  | Komposisi Pulp (Broke) tidak sesuai standar             | 7                   | 7                    | 2                    | 98                        |
| 3  | Tingkat Kebisingan Tinggi                               | 8                   | 4                    | 3                    | 96                        |
| 4  | Kurangnya Ventilasi                                     | 7                   | 4                    | 3                    | 84                        |
| 5  | Kelelahan                                                | 6                   | 4                    | 3                    | 72                        |
| 6  | Komposisi Retention Aid tidak sesuai standar            | 5                   | 4                    | 2                    | 70                        |
| 7  | Komposisi Filler Flow tidak sesuai standar              | 5                   | 4                    | 2                    | 70                        |
| 8  | Komposisi Retention Aid tidak sesuai standar           | 4                   | 3                    | 1                    | 12                        |

Source: Data Processed

Based on data analysis result Failure Mode and Effect Analysis obtained RPN value (Risk Priority Number) from start of the largest to the smallest. Here are the results of Failure Mode and Effect Analysis from Thickness defect, Tensile Strength, and Smoothness of Jumbo Roll products as follows:

1. Based on Failure Mode and Effect Analysis on Thickness defect from Jumbo Roll found that the biggest RPN (Risk Priority Number) value is the non-standard refiner part with RPN (Risk Priority Number) value of 324.
2. Based on Failure Mode and Effect Analysis on Tensile Strength defect from Jumbo Roll found that the biggest RPN (Risk Priority Number) value is the composition of pulp (NBKP) is not in accordance with the standard value of RPN (Risk Priority Number) of 112.
3. Based on the Failure Mode and Effect Analysis of Smoothness defect from Jumbo Roll found that the highest RPN (Risk Priority Number) value is the refiner part is not in accordance with the standard value of RPN (Risk Priority Number) of 112.

Based on RPN (Risk Priority Number) results from FMEA (Failure Mode and Effect Analysis) analysis. Thus, from the results of the largest RPN (Risk Priority Number) value is then performed improvements with the aim to reduce the defect. The proposed improvements that can be done based on the analysis of FMEA (Failure Mode and Effect Analysis) are as follows:

| Types of Defect | Potential Causes Factor | Proposed Improvement |
|-----------------|-------------------------|----------------------|
| Thickness       | The refiner section is not up to the standard | Perform regular maintenance on the part of the refiner such as knife and motor refiner |
| Tensile Strength| Pulp composition (NBKP) is not up the standard | Setting for pulp composition (NBKP) in accordance with standard pulp composition (NBKP) on each type of paper |
| Smoothness      | The refiner section is not up to the standard | Setting the amperes on the refiner to match the ampere that has been set in accordance with the standard ampere on the paper type |

Source: Data Processed

Based on table 10 that there are several proposed improvements that will be made to correct the defect Thickness, Tensile Strength, and Smoothness are as follows:

1. Proposed repair for Thickness defect is doing regular maintenance on the part of the refiner such as knife and motor refiner.
2. Proposed refinement for Tensile Strength defect is to set the pulp composition (NBKP) in accordance with standard pulp composition (NBKP) on each type of paper.
3. Proposed improvement for Smoothness defect is to make ampere setting on the refiner to match the ampere that has been set in accordance with the standard ampere on the paper type.

4.4. Analysis 5W + 1H

1. 5W + 1H Analysis of Proposed Thickness Defect Repair

| Types of Defect | Causative factor | What | Why | Where | When | Who | How |
|-----------------|------------------|------|-----|-------|------|-----|-----|
| Defect of Thickness | The refiner section is not up to standard | What is the repair plan? | Why Need a Repair? | Where are the repairs done? | When is the repair done? | Who is the PIC in the repair? | How to make these improvements? |

The Department of Engineering repaired less optimum refiner parts such as motor and refiner.
2. **5W + 1H Analysis of Proposed Tensile Strength Defect Repair**

| Types of Defect | Causative factor | What | Why | Where | When | Who | How |
|-----------------|------------------|------|-----|-------|------|-----|-----|
| Defect of Tensile Strength | Pulp composition (NBKP) is not up standard | What is the repair plan? | Why Need a Repair? | Where are the repairs done? | When is the repair done? | Who is the PIC in the repair? | How to make these improvements? |
| | Set the pulp composition (NBKP) according to the standard | To minimize Tensile Strength defect | Improvements were made to the pulper chest section of Stock Preparation | Repairs are done according to the time when the paper type production changes | Operator on the pulper chest in Stock Preparation | The operator in the pulper chest sets the pulp composition (NBKP) according to the standard |

3. **5W + 1H Analysis of Proposed Smoothness Defect Repair**

| Types of Defect | Causative factor | What | Why | Where | When | Who | How |
|-----------------|------------------|------|-----|-------|------|-----|-----|
| Defect of Smoothness | The refiner section is not up to standard | What is the repair plan? | Why Need a Repair? | Where are the repairs done? | When is the repair done? | Who is the PIC in the repair? | How to make these improvements? |
| | Setting the amperes on the refiner to match the ampere that has been set in accordance with the standard ampere | To minimize the defect of Smoothness Jumbo Roll products | Repairs are done on the refiner section in Stock Preparation | Repairs are done according to the time when the paper type production changes | Operator on the refiner section in Stock Preparation | The operator on the refiner does the ampere setting on the refiner part |

5. **Conclusion**

Based on the results of research that has been done on Jumbo Roll products in PT. Indah Kiat Pulp & Paper, Tbk, the conclusion that can be taken from this research is as follows:

1. Based on the Pareto Chart principle known as the 80/20 principle which means 80% caused by 20% of factors. So, in this research there are 3 types of defect with total cumulative percentage is in the number 80% that is Thickness defect equal to 51.89%, Tensile Strength defect equal to 25.90%, and Smoothness defect equal to 14.29%, so the main improvement is focused on three types of defects.

2. Based on the analysis that has been done by using FTA (Fault Tree Analysis) found the cause of Thickness defect, Tensile Strength defect, and Smoothness defect on Jumbo Roll product at PT. Indah Kiat Pulp & Paper, Tbk is man, material, and machine.

3. The proposed improvements that can be done to perform defects repair process of Thickness, Tensile Strength, and Smoothness based on RPN (Risk Priority Number) largest from FMEA (Failure Mode and Effect Analysis) analysis are as follows:
   a. Proposed repair Thickness defect is doing regular maintenance on the part of the refiner such as knife and motor refiner.
   b. The proposed Tensile Strength defect improvement is setting the pulp composition (NBKP) according to the pulp composition standard (NBKP) on each paper type.
   c. The proposed Smoothness defect improvement is to perform the ampere setting on the refiner to match the ampere that has been set in accordance with the standard ampere on the paper type.
After the proposed improvement based on the largest RPN (Risk Priority Number) based on the analysis of FMEA (Failure Mode and Effect Analysis), then 5W + 1H analysis is performed to make improvements are as follows:

a. Based on the analysis of 5W + 1H for the proposed Thickness defect repair is a periodic maintenance on the refiner in Stock Preparation, by way of the Department of engineering to improve the less optimum part of the refiner such as motor and refiner blades.

b. Based on the analysis of 5W + 1H for the proposed Tensile Strength defect repair is to set the pulp composition (NBKP) according to the standard pulp composition (NBKP) on each paper type, by the operator on the pulper chest setting the pulp composition (NBKP) according to the composition standard pulp (NBKP) type of paper to be in production.

c. Based on the analysis of 5W + 1H for the improvement proposal Smoothness defect is to do the ampere setting on the refiner to match the ampere that has been set in accordance with the standard ampere on the paper type, by the operator to do ampere setting on the refiner with the aim that the blade can be more standardized.

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