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# *Defect Analysis Using Failure Mode and Effects Analysis and Fault Tree Analysis (Case Study: Secondary Section PT PID Ongkowidjojo)*

Elvina Pramono[1, a)], Sunday Noya[1, b)], Yurida Ekawati[1, c)]

*Author Affiliations*
*[1]Industrial Engineering Program Study, Faculty of Technology and Design, Universitas Ma Chung*
*Jalan Villa Puncak Tidar N-01, Malang, Indonesia 65151*

*Author Emails*
*[a)] 412010003@student.machung.ac.id**
*[b)] sunday.alexander@machung.ac.id*
*[c)] yurida.ekawati@machung.ac.id*

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**Abstract.** Quality control is a vital aspect of product manufacturing, ensuring adherence to predefined standards and meeting consumer expectations. This study focuses on quality control within the cigarette production process, specifically in PT PID Ongkowidjojo, a prominent manufacturer located in Malang, Indonesia. Despite meticulous production processes, defects in cigarette sticks persist, leading to waste of resources, time, and potential degradation in product quality. The research employs Failure Mode and Effects Analysis (FMEA) and Fault Tree Analysis (FTA) to identify, analyze, and propose solutions for defects occurring in the maker machine division. Initial analysis reveals common defects such as glue inadequacy, tears in wrappers, and tobacco density inconsistencies, prompting the need for systematic improvements. Through FMEA and FTA methodologies, root causes of defects are pinpointed, and corrective actions are proposed. Implementation of these measures results in a reduction of Risk Priority Number (RPN) values for major defects, indicating a positive impact on production quality. However, limitations in utilizing gate symbols within FTA are acknowledged, suggesting avenues for future research to optimize analytical techniques. This study contributes to the ongoing discourse on quality control in manufacturing industries, particularly in addressing common defects in cigarette production. By integrating FMEA and FTA methodologies, it offers insights into effective defect mitigation strategies, highlighting the importance of continuous improvement in maintaining product quality and operational efficiency.

**Keywords:** Cigarette production; Defect mitigation; Failure mode and effects analysis (FMEA), Fault tree analysis (FTA); Manufacturing industry; Quality control.

## 1. Introduction

Quality is the excellence value of a product that reflects a company's ability to meet predetermined quality requirements and qualifications, or even exceed consumer expectations (Razak et al., 2019). Product quality is the ability of a product to perform its functions, such as product durability and reliability, ease of operation and maintenance, taste value, and product

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aesthetics, among others (Napitupulu, 2019). Quality must be continuously maintained and preserved using quality control. This is crucial to consistently maintain products in the market and compete in the business industry (Revita et al., 2021). Quality control is a technical and managerial activity that assesses the quality characteristics of products and services. The measurement results are then compared with predetermined specifications. The comparison results between specifications and measurements will be followed up according to existing SOPs to continually improve productivity in the production process (Shiyami et al., 2021). Quality control is an activity that ensures a product meets specific quality standards set by the company, ranging from the quality of the production process, quality of raw materials, quality of the raw material processing process to finished goods, and also the standards for distribution to consumers in the most effective and efficient manner (Riadi, 2020).

PT PID Ongkowidjojo is one of the cigarette manufacturing companies located in the city of Malang. In the production process of cigarettes, there are two divisions, namely primary and secondary. Primary is the cigarette division that processes raw tobacco into sauced tobacco, while secondary is the division that manages sauced tobacco into packaged and ready-to-distribute cigarettes or Machine-Made Clove Cigarettes (SKM). In the secondary division, there are three types of machines, one of which is the Maker machine (MK). This machine functions to turn sauced tobacco into cigarette sticks or Machine-Made Clove Cigarettes (SKM) ready for consumption (not yet in packaging). These cigarette sticks consist of several components, including filters, wrappers, sauced tobacco, glue, and tipping paper.

The production process is carried out to produce cigarette sticks ready for consumption. However, not all cigarette sticks produced can be consumed or pass the quality check. There are many types of defects obtained from the production of cigarette sticks, such as: glue not adhering between the wrapper and tipping paper, tears in the cigarette wrapper (wrapper), insufficient tobacco density in the cigarette, resulting in a porous appearance, uneven cutting size of the tipping paper, and many more. These types of defective products undoubtedly affect the quality of production. In addition to product quality, this can impact the repetition of processes, leading to ineffective and inefficient production processes. The number of samples and the quantity of defects from July 20, 2023, to July 31, 2023, can be seen in Table 1.

**Table 1** Number of Samples and Quantity of Defects in Cigarette

| Date (2023) | Number of Sample | Type of Defects | | | | | | | Quantity of Defects |
|---|---|---|---|---|---|---|---|---|---|
| | | A | B | C | D | E | F | G | |
| July, 20 | 240 | 5 | 19 | | | | | | **24** |
| July, 21 | 240 | | 37 | 4 | | | | | **41** |
| July, 22 | 240 | 9 | 6 | 6 | | | | | **21** |
| July, 24 | 240 | | 20 | | | | | | **20** |
| July, 25 | 240 | | 27 | | 10 | 22 | | | **59** |
| July, 26 | 240 | | 18 | | | 10 | 15 | 18 | **61** |
| July, 27 | 240 | | 11 | | | | 12 | 4 | **27** |
| July, 28 | 240 | | 8 | | 6 | | 21 | | **35** |
| July, 30 | 240 | 26 | | | 50 | | | | **76** |
| July, 31 | 240 | 32 | 8 | | | | | 8 | **48** |
| **Total Quantity of Defect** | | **72** | **154** | **10** | **66** | **32** | **48** | **30** | **412** |

Explanation:
A. Tears on Wrapper
B. Porous/Density not appropriate
C. Improper Overlap (2 mm)
D. Wrapper and tipping paper not adhering
E. Varying diameters
F. Varying lengths of tipping paper
G. Absence of filter

Based on the data above, it can be seen that there are 412 defects out of 2400 samples. This will result in excessive use of raw materials and may affect the taste of the cigarettes. Additionally, unnecessary process repetitions can waste time, energy, and costs. The quantity of defective

products will be dismantled and reprocessed, requiring additional time, costs, raw materials, and manpower to repeat the process. Moreover, the taste produced from the reprocessed tobacco may be diminished, impacting consumer interest in PT PID Ongkowidjojo's cigarette products. This, in turn, leads to ineffective and inefficient production processes. Therefore, this study conducts a failure analysis based on each process in the maker machine using the FMEA method. Causes, effects, and corrective solutions will be identified using the Fault Tree Analysis (FTA) method by (Alijoyo et al., 2021). Subsequently, the FMEA method will be used as a tool to compare the results of the proposed improvements in the cigarette production process at PT PID Ongkowidjojo, as suggested by (Alijoyo et al., 2017).

According to (Alfarizi et al., 2022), FMEA can be used in conjunction with Six Sigma to reduce the number of defective products, as demonstrated in their study titled "Quality Control Using Six Sigma and FMEA to Reduce Reject Material Preform in Bottled Drinking Water Industry." Additionally, FMEA can be paired with Fault Tree Analysis (FTA) to reduce defective products, as seen in the study titled "Application of Fault Tree Analysis Method to Prevent Failures in the Interior Department at PT X" by (Yolanda et al., 2023). FMEA can also be combined with the SWOT method to enhance quality, as demonstrated in the study titled "Marketing Strategy Design and Improvement of Bird Feed Product Quality at IKM Sinar Mas Malang using SWOT and FMEA" by (Susanto & Purnomo, 2022).

## 2. Methods

This research focuses on the random sampling of a population consisting of machine-made cigarette sticks. Samples are taken randomly, with 50 sticks sampled every few hours at random times. Typically, researchers conduct sampling five times, totaling 250 cigarette sticks. These samples are then checked for defects. The defects found on the cigarettes are counted and entered into a Google Form as a data collection tool during the research period. Data collection takes approximately three months, with a total sample of 16,000 cigarette sticks. Once the data is gathered, researchers need to analyze it according to the following procedures.

The first analysis conducted is by analyzing the mode and impact of failures using Failure Mode and Effects Analysis (FMEA). Failure mode analysis is done by identifying potential failures in each production process. Next, analyzing the causes of failure, and controlling them with Fault Tree Analysis (FTA). At this stage, each process analyzed with FMEA will be detailed using a failure tree. Each type of failure impact will be analyzed for its causes one by one. The next step is to determine the weights of the Severity, Occurrence, and Detection components. Weight determination is based on the impact resulting from the types of defects. The more severe and impactful the defect, the higher the assigned value. Once the Severity, Occurrence, and Detection weights are assigned, these values will be calculated for the Risk Priority Number (RPN) using the formula S x O x D. The RPN values will be sorted from highest to lowest, and defects with the highest values will be prioritized for correction first.

The prioritization sequence from the RPN values will be used as the basis for proposing improvement recommendations. After each defect receives improvement proposals, these proposals need to be implemented over some time. During the implementation process of improvement proposals, researchers need to measure defect data on the machine makers that have undergone implementation over a certain period. Afterward, this data will be used to calculate the final RPN based on the Severity, Occurrence, and Detection values of the defects after improvement. Once the final RPN value is determined, researchers can conduct a comparative analysis. This comparative analysis contains the results of comparing the initial and final RPN calculations. The analysis results will show whether the implemented improvement proposals can reduce the number of defective products.

## 3. Results and Discussion

The research data consists of a combination of primary and secondary data obtained from the quality control division of PT PID Ongkowidjojo. The summarized data of the cigarette stick quality checks from August to October can be seen in Table 2.

**Table 2** Summary of Defective Quantity Data for the Period of August-October 2023

| Type of Defects | Quantity of Defects | Percentage of Defects |
|---|---|---|
| Tears on the Wrapper | 699 | 24,96% |
| Porous/Density not Appropriate | 1279 | 45,66% |
| Improper Overlap (2 mm) | 51 | 1,82% |
| Wrapper and Tipping Paper not Adhering | 435 | 15,53% |
| Varying Diameters | 119 | 4,25% |
| Varying Lengths of Tipping Paper | 121 | 4,32% |
| Absence of Filter | 97 | 3,46% |
| **Total** | **2801** | **100%** |

Based on the summarized data above, it can be observed that the highest defect percentage is attributed to porous defects, accounting for 45.66%. Subsequently, the second-largest defect is tears on the wrapper at 24.96%, and the third-largest defect is the detachment of tipping and wrapper at 15.53%. These three defects collectively constitute over 80% of the overall defect percentage. This indicates that these three defects have the highest frequency factor (O) in their occurrences. The seven types of defects in Table 2 will be analyzed, and their corrective measures will be determined using the FMEA and FTA methods.

**Table 3** Failure Analysis and Failure Consequence Table

| Activities in the Process | Failure Mode Potential | Impact of Failure Potential |
|---|---|---|
| Rolling and Tipping of Cigar Wrapper | *Wrapper roll not straight/there is a bend in the wrapper roll* | Tears on the Wrapper |
| | The size of the cigarette wrapper folding is not appropriate | Improper Overlap (2 mm) |
| | | Varying Diameters |
| Filling tobacco in the wrapper | There is crushed tobacco | Porous/Density not appropriate |
| | The tobacco texture is too wet (moist) | |
| | The tobacco weight adjustment on the machine has not been set | |
| | There is other material besides tobacco | Tears on the Wrapper |
| Cutting the tobacco-filled wrapper | Dirty machine (sharp objects have not been cleaned) | Tears on the Wrapper |
| Filter cutting | The operator does not arrange the filters according to the cutting machine | Absence of Filter |
| Combining the tobacco-filled wrapper with the filter and tipping | Dried glue on the machine has not been cleaned | Wrapper and Tipping Paper not Adhering |
| | Glue is empty and not filled | |
| | The cutting knife of the tipping is tilted | Varying Lengths of Tipping Paper |
| | The cutting knife of the tipping has not been cleaned | |
| Automatic sensor checking | There is a problem with the electrical part | Tears on the Wrapper |
| | | Porous/Density not appropriate |
| | | Varying Diameters |
| | | Wrapper and Tipping Paper not Adhering |
| | | Absence of Filter |

After identifying the failures in each process, the next step is to find the root causes of these incidents. One method that can be used to determine the causes of defects is Fault Tree Analysis (FTA). The cause analysis using the FTA method for each type of defect is as follows:

The presence of tears in the wrapper can be caused by one of three factors: human error, machinery, and raw materials. Human error can lead to this defect when operators sometimes forget or fail to check whether the cigar wrapper roll is straight or bent. If the used wrapper is bent, it will result in the wrapper tearing when pulled by the machine. Additionally, operators often neglect to clean the entire machine. Typically, the machine is cleaned only when a defect is detected, and the machine is temporarily stopped for cleaning. Ideally, before the production process begins, operators should thoroughly clean the machine. A solution derived from the human factor is the implementation of a checklist containing specific tasks to be performed in a written format before initiating the production process. This checklist will be provided to the operators and must be completed and filled out before the production process begins.

The second factor contributing to wrapper tears is the machinery. After all production processes are completed, all cigars go through a sensor process that sorts defective and distribution-worthy cigars. If this machine fails to operate, defective cigars can exit the sensor without proper sorting. A corrective solution is the implementation of regular maintenance or checks on the machine's electrical components, conducted on a monthly basis.

The third factor causing wrapper tears is the raw materials. The primary raw materials for cigars are tobacco and cloves. The tobacco used is a mixture of sauces tobacco combined with *koncek* tobacco resulting from the disassembly of defective cigars. Additionally, the wrapper can tear if there are materials other than tobacco and cloves. These materials usually have a sharp shape that can scratch the wrapper, causing it to tear, such as staple contents, sharp pieces of clove stems, and others. A preventive solution is to use foreign object detection devices such as metal detectors or others.

The defect of wrapper tears or inadequate density can occur due to three factors: machinery, raw materials, and environmental conditions. The first factor is machinery. In the maker machine, there is a process of filling the wrapper with tobacco regulated based on the tobacco's weight. The weight regulation machine sometimes does not match the set figure by the operator, requiring frequent checks by the operator. The second issue lies in the process of suctioning tobacco to be inserted into the wrapper. This machine can also get stuck with tobacco, reducing its pulling force. The consequence of reduced pulling force is insufficient tobacco entering the wrapper, causing the cigar to be porous as the wrapper is not fully filled. The corrective solution for operators is the implementation of a checklist containing tasks to be checked and performed before the production process starts.

After cigars experience porosity, they are usually automatically discarded by the sensor machine as defective. However, if the sensor machine malfunctions, porous cigars may proceed to the packaging stage without manual checks by QC and operators. The corrective solution for the sensor machine is regular maintenance by the electrical department once a month.

The factor causing the porosity defect is the raw material, where crushed tobacco exceeding the specified proportion is found among the overall tobacco. If the amount of crushed tobacco exceeds the specification, the tobacco in the cigar will have a very fine texture with a weight similar to other cigars. If the tobacco in the cigar is fine, there is a high likelihood that it can fall out, causing the cigar to be porous. The solution for this factor is thorough mixing of crushed and sauces tobacco with the right proportions.

The third factor causing porosity is unpredictable temperature and weather changes. Tobacco is stored in a cool room in the WIP warehouse using air conditioning. However, the secondary production process takes place in an open area with a temperature dependent on the weather. This exposes the tobacco to moisture during rain, making it damp and heavier. Excessive weight will make the cigar porous because the tobacco is filled based on its weight. On the other hand, hot weather can make the tobacco drier, resulting in lighter tobacco weight. Therefore, when dry tobacco is filled into the cigar, it becomes denser than a regular cigar. The solution is to have an

enclosed space with temperature control to maintain humidity in the secondary SKM production area.

The defect of misaligned overlap refers to an overlap that is more or less than 2 mm. This can occur due to the operator's negligence in adjusting the size of the cigar wrapper folding machine. The size of the wrapper roll used usually varies, depending on the supplier of the wrappers. When there is a change in the type of wrapper, the folding machine must be adjusted to the new size to achieve a 2 mm overlap. This issue can be addressed by providing a checklist to the operator as a reminder of the tasks to be completed before the production process starts.

The defect of the wrapper and tipping paper not adhering originates from human and machine factors. This can be caused by dried adhesive from the previous production process that hasn't been cleaned by the operator. Additionally, it can occur if the operator fails to check the availability of adhesive on the machine, causing the machine to operate without adhesive. This can be addressed by providing a checklist outlining tasks for the operator to perform before the production process begins.

A machine-related factor that can contribute to this issue is the failure of the sensor machine to detect defective cigars. If the sensor machine malfunctions, defective cigars may proceed to the packaging stage without manual checks by QC and operators. The corrective solution for the sensor machine is to conduct monthly maintenance by the electrical department.

The defect of varying diameters refers to diameters that are either more or less than 8 mm. This can occur due to the operator's negligence in adjusting the size of the cigar wrapper folding machine. The size of the wrapper roll used usually varies, depending on the supplier of the wrappers. When there is a change in the type of wrapper, the folding machine must be adjusted to the new size to achieve an 8 mm diameter. This issue can be addressed by providing a checklist to the operator as a reminder of the tasks to be completed before the production process starts.

The defect of varying lengths of tipping paper originates from human factors. This can be caused by a slightly tilted knife that goes unchecked by the operator. Additionally, it can occur due to a knife that is dirty from tobacco but hasn't been cleaned by the operator. This can be addressed by providing a checklist outlining tasks for the operator to perform before the production process begins.

The defect of the absence of filters can be caused by human or machine factors. Human factors may result from the operator's negligence in arranging the filter's position. Thus, when the filter is inserted into the machine, it gets stuck at the entrance of the cutting machine. This causes the machine for filling the wrapper with tobacco to continue running while the filter cutter stops. Consequently, it leads to the production of cigarettes without filters. This can be rectified by providing a checklist to the operator that includes tasks to be done and checked before initiating the production process.

The second factor causing the absence of filters is the poor performance of the sensor machine. This is often due to inadequate maintenance from the electrical department. Therefore, the corrective solution provided is to conduct monthly maintenance.

The results of the Fault Tree Analysis (FTA) created will serve as input for Failure Mode and Effect Analysis (FMEA), particularly in identifying potential root causes of failures. The goal of FMEA analysis is to identify improvement suggestions that can reduce the number of failures and prevent failures in the production process of SKM cigarettes. The scores or weight values used in the FMEA analysis are obtained from observations and interviews with the QC supervisor. The results of the FMEA analysis can be seen in Table 4.

**Table 4** FMEA Analysis

| | | | | | Before Improvement | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Activities in the Process** | **Failure Mode** | **Impact of Failure** | **Causes** | **Control** | **S** | **O** | **D** | **RPN** | **Recommendations for Improvement** |
| Rolling and Tipping of Cigar Wrapper | *Wrapper roll not straight/there is a bend in the wrapper roll* | Tears on the Wrapper | The operator has not checked before the production process | Checking the bends in the wrapper roll | 7 | 6 | 4 | 168 | Creating a checklist containing a 'To-Do List' before production |
| | The size of the cigarette wrapper folding is not appropriate | Improper Overlap (2 mm) | The operator did not set the size before the production process | Setting the folding size before starting production | 2 | 5 | 3 | 30 | Creating a checklist containing a 'To-Do List' before production |
| | | Varying Diameters | The operator did not set the size before the production process | Setting the folding size before starting production | 2 | 5 | 3 | 30 | Creating a checklist containing a 'To-Do List' before production |
| Filling tobacco in the wrapper | There is crushed tobacco | Porous/Density not appropriate | The mixing process of crushed and sauces tobacco is not be spread evenly | Mixing at the right location | 7 | 7 | 8 | 392 | Mixing crushed tobacco in the primary section |
| | The tobacco texture is too wet (moist) | | Unpredictable changes in temperature and weather | Closing the storage and production room to maintain temperature | 7 | 7 | 6 | 294 | Providing temperature control (AC) in the Secondary SKM section |
| | The tobacco weight adjustment on the machine has not been set | | The operator did not check the machine before the production process | Ensuring the tobacco weight is correct | 7 | 7 | 4 | 196 | Creating a checklist containing a 'To-Do List' before production |
| | There is other material besides tobacco | Tears on the Wrapper | The operator is less meticulous in the inspection process | Double-checking sharp objects on the tobacco | 7 | 6 | 9 | 378 | Providing sharp object detection tools |
| Cutting the | Dirty machine | Tears on the Wrapper | The operator | Conducting | 7 | 6 | 5 | 210 | Scheduling periodic |

| | | | | | Before Improvement | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Activities in the Process** | **Failure Mode** | **Impact of Failure** | **Causes** | **Control** | **S** | **O** | **D** | **RPN** | **Recommendations for Improvement** |
| tobacco-filled wrapper | (sharp objects have not been cleaned) | | did not clean the machine thoroughly | thorough cleaning of the machine parts | | | | | thorough cleaning |
| Filter cutting | The operator does not arrange the filters according to the cutting machine | Absence of Filter | The operator is not meticulous in the pre-production inspection | Ensuring the correct position of the filter before starting the production machine | 8 | 5 | 4 | 160 | Creating a checklist containing a 'To-Do List' before production |
| Combining the tobacco-filled wrapper with the filter and tipping | Dried glue on the machine has not been cleaned | Wrapper and Tipping Paper not Adhering | The operator is less meticulous in machine inspection | Conducting a more thorough cleaning of the machine | 7 | 6 | 4 | 168 | Scheduling periodic thorough cleaning |
| | Glue is empty and not filled | | The operator is less meticulous in machine inspection | Conducting a more thorough cleaning of the machine | 7 | 6 | 4 | 168 | Creating a checklist containing a 'To-Do List' before production |
| | The cutting knife of the tipping is tilted | Varying Lengths of Tipping Paper | The operator is less meticulous in machine inspection | Conducting a more thorough cleaning of the machine | 4 | 5 | 4 | 80 | Creating a checklist containing a 'To-Do List' before production |
| | The cutting knife of the tipping has not been cleaned | | The operator is less meticulous in machine inspection | Conducting a more thorough cleaning of the machine | 4 | 5 | 4 | 80 | Scheduling periodic thorough cleaning |
| Automatic sensor checking | There is a problem with the electrical part | Tears on the Wrapper | The machine lacks maintenance | Establishing a regular maintenance schedule | 7 | 6 | 4 | 168 | Scheduling maintenance with the electrical section every month |
| | | Porous/Density not appropriate | The machine lacks maintenance | Establishing a regular maintenance schedule | 7 | 7 | 4 | 196 | Scheduling maintenance with the electrical section every month |
| | | Varying Diameters | The machine lacks maintenance | Establishing a regular maintenan | 2 | 5 | 4 | 40 | Scheduling maintenance with the electrical |

| | | | | | Before Improvement | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Activities in the Process** | **Failure Mode** | **Impact of Failure** | **Causes** | **Control** | **S** | **O** | **D** | **RPN** | **Recommendations for Improvement** |
| | | | | ce schedule | | | | | section every month |
| | | Wrapper and Tipping Paper not Adhering | The machine lacks maintenance | Establishing a regular maintenance schedule | 7 | 6 | 4 | 168 | Scheduling maintenance with the electrical section every month |
| | | Absence of Filter | The machine lacks maintenance | Establishing a regular maintenance schedule | 8 | 5 | 4 | 160 | Scheduling maintenance with the electrical section every month |

Based on the FMEA table above, a summary of the average RPN values for each type of defect is obtained, as shown in Table 5.

**Table 5** Average RPN for Type of Defects

| No | Type of Defects | Average RPN | Categories |
|---|---|---|---|
| 1 | Tears on the Wrapper | 231 | High |
| 2 | Porous/Density not Appropriate | 269,5 | High |
| 3 | Improper Overlap (2 mm) | 30 | Low |
| 4 | Wrapper and Tipping Paper not Adhering | 168 | Medium |
| 5 | Varying Diameters | 35 | Low |
| 6 | Varying Lengths of Tipping Paper | 80 | Low |
| 7 | Absence of Filter | 160 | Medium |

The type of defect with the highest RPN is porosity. The recommended handling proposed by the researcher is the implementation of a Checklist Form for the Production Operator's "To-Do List." This checklist form is expected to prevent operator errors and address machine performance issues during production. The form will be filled out by the supervisor by placing a checkmark after the operator completes the procedures outlined in the checklist. The checklist provided to the SKM cigarette production supervisor can be seen in Table 6.

**Table 6** Operator Pre-Production Checklist Form

| Tanggal/ shift Cth: (1/11/23) / 1 | Cek kondisi *Roll* Ambri | Mengatur ukuran *overlap*/ diameter rokok di maker | Mengatur ukuran berat tembakau maker | Mengecek posisi *filter* rokok | Mengecek jumlah lem dalam mesin | Membersihkan mesin, pisau, dan lem yang ada pada mesin | Memeriksa posisi mesin pemotong ambri | Memeriksa posisi mesin pemotong *filter* | Memeriksa posisi mesin pemotong *tipping* | Ttd Mandor |
|---|---|---|---|---|---|---|---|---|---|---|

Another recommended improvement to prevent porous cigarettes is to reprocess the crushed tobacco so that it has the same weight as regular sauces tobacco. This improvement involves reprocessing the crushed tobacco in the primary section by adding sauce and alcohol to it. The researcher also suggests an improvement recommendation in the form of adding a room temperature control device in the production area to maintain the humidity stability of sauces tobacco during processing. Another recommendation that can be implemented to reduce porosity in cigarettes is a general cleaning of the machines.

For the second highest average RPN defect, which is tears in the wrapper, the researcher recommends implementing a sharp object detection tool to prevent wrapper tears. For defects categorized as medium and low, a general improvement that can be made is to establish a regular maintenance schedule, typically on a monthly basis. In addition to maintenance, measures to prevent defects in the production process can include socializing complaints from QC about failed products, which will then be conveyed by supervisors to operators. This socialization should be conducted whenever defects are identified by QC. In addition to socialization, supervisors or production managers should also conduct briefings at the beginning of each shift before production.

Not all recommended measures can be implemented due to budget limitations of the company. Some feasible recommendations include creating a checklist form to prevent operator negligence before the production process begins. Another recommended measure is to conduct more detailed cleaning at the start of each shift to reduce the possibility of defective cigarettes due to dirty machine factors. The third recommended measure is to mix crushed tobacco in the primary section so that it acquires flavor and can be evenly mixed with sauces tobacco. This is done to reduce the type of defect related to porosity. The fourth recommendation is to conduct socialization with operators before starting production. This is done to help operators remember what needs to be done and to evaluate the shifts from previous days. It helps reduce operator negligence in the production process of cigarettes and ensures uniform information to all operators. The implementation of these improvements took place over two weeks with data as shown in Table 7.

**Table 7** Table of Measurement Final Type of Defects

| Date | Number of Sample | Type of Defects | | | | | | | Quantity of defects |
|---|---|---|---|---|---|---|---|---|---|
| | | A | B | C | D | E | F | G | |
| 20/11/2023 | 250 | 25 | | | 10 | 8 | | | 43 |
| 21/11/2023 | 250 | 10 | 25 | | 4 | 5 | | | 44 |
| 22/11/2023 | 250 | | 11 | 6 | | | | | 17 |
| 23/11/2023 | 250 | | | | | | 8 | | 8 |
| 24/11/2023 | 250 | | | | | 6 | 5 | | 11 |
| 27/11/2023 | 250 | 12 | 25 | 5 | 20 | | 6 | 10 | 78 |
| 28/11/2023 | 250 | 18 | | | | | 2 | 3 | 23 |
| 29/11/2023 | 250 | | 16 | | | | | | 16 |
| 30/11/2023 | 250 | | 9 | 7 | | | | | 16 |
| 01/12/2023 | 250 | 14 | | | | | 4 | | 18 |
| 04/12/2023 | 250 | 20 | 16 | | 14 | 5 | | | 55 |
| **Total** | **2750** | **99** | **102** | **18** | **48** | **24** | **25** | **13** | **329** |

Explanation:
A. Tears on Wrapper
B. Porous/Density not appropriate
C. Improper Overlap (2 mm)
D. Wrapper and tipping paper not adhering
E. Varying diameters
F. Varying lengths of tipping paper
G. Absence of filter

After the data collection following the implementation was conducted, the RPN values after the implementation also need to be evaluated, as shown in Table 8.

**Table 8** FMEA Analysis Before dan After Improvement

| | | | Before Improvement | | | | | After Improvement | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Activities in the Process** | **Failure Mode** | **Impact of Failure** | **S** | **O** | **D** | **RPN** | **Recommendations for Improvement** | **S** | **O** | **D** | **RPN** |
| Rolling and Tipping of | *Wrapper roll not straight/ther* | Tears on the Wrapper | 7 | 6 | 4 | 168 | Creating a checklist containing a 'To- | 7 | 6 | 3 | 126 |

| | | | Before Improvement | | | | | After Improvement | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Activities in the Process** | **Failure Mode** | **Impact of Failure** | **S** | **O** | **D** | **RPN** | **Recommendations for Improvement** | **S** | **O** | **D** | **RPN** |
| Cigar Wrapper | *e is a bend in the wrapper roll* | | | | | | Do List' before production | | | | |
| | The size of the cigarette wrapper folding is not appropriate | Improper Overlap (2 mm) | 2 | 5 | 3 | 30 | Creating a checklist containing a 'To-Do List' before production | 2 | 5 | 3 | 30 |
| | | Varying Diameters | 2 | 5 | 3 | 30 | Creating a checklist containing a 'To-Do List' before production | 2 | 5 | 3 | 30 |
| Filling tobacco in the wrapper | There is crushed tobacco | Porous/Density not appropriate | 7 | 7 | 8 | 392 | Melakukan pecampuran tembakau *koncek* di bagian *primary* | 7 | 6 | 3 | 126 |
| | The tobacco texture is too wet (moist) | | 7 | 7 | 6 | 294 | Melakukan pecampuran tembakau *koncek* di bagian *primary* | 7 | 6 | 3 | 126 |
| | The tobacco weight adjustment on the machine has not been set | | 7 | 7 | 4 | 196 | Creating a checklist containing a 'To-Do List' before production | 7 | 6 | 2 | 84 |
| | There is other material besides tobacco | Tears on the Wrapper | 7 | 6 | 9 | 378 | Melakukan sosialisasi sebelum memulai produksi | 7 | 6 | 3 | 126 |
| Cutting the tobacco-filled wrapper | Dirty machine (sharp objects have not been cleaned) | Tears on the Wrapper | 7 | 6 | 5 | 210 | Scheduling periodic thorough cleaning | 7 | 6 | 3 | 126 |
| Filter cutting | The operator does not arrange the filters according to the cutting machine | Absence of Filter | 8 | 5 | 4 | 160 | Creating a checklist containing a 'To-Do List' before production | 8 | 5 | 3 | 120 |
| Combining the tobacco-filled wrapper with the filter and tipping | Dried glue on the machine has not been cleaned | Wrapper and Tipping Paper not Adhering | 7 | 6 | 4 | 168 | Scheduling periodic thorough cleaning | 7 | 6 | 3 | 126 |
| | Glue is empty and not filled | | 7 | 6 | 4 | 168 | Creating a checklist containing a 'To-Do List' before production | 7 | 6 | 3 | 126 |

| Activities in the Process | Failure Mode | Impact of Failure | Before Improvement S | O | D | RPN | Recommendations for Improvement | After Improvement S | O | D | RPN |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | The cutting knife of the tipping is tilted | Varying Lengths of Tipping Paper | 4 | 5 | 4 | 80 | Creating a checklist containing a 'To-Do List' before production | 4 | 5 | 4 | 80 |
| | The cutting knife of the tipping has not been cleaned | | 4 | 5 | 4 | 80 | Scheduling periodic thorough cleaning | 4 | 5 | 4 | 80 |
| Automatic sensor checking | There is a problem with the electrical part | Tears on the Wrapper | 7 | 6 | 4 | 168 | Scheduling maintenance with the electrical section every month | 7 | 6 | 4 | 168 |
| | | Porous/Density not appropriate | 7 | 7 | 4 | 196 | Scheduling maintenance with the electrical section every month | 7 | 6 | 4 | 168 |
| | | Varying Diameters | 2 | 5 | 4 | 40 | Scheduling maintenance with the electrical section every month | 2 | 5 | 4 | 40 |
| | | Wrapper and Tipping Paper not Adhering | 7 | 6 | 4 | 168 | Scheduling maintenance with the electrical section every month | 7 | 6 | 4 | 168 |
| | | Absence of Filter | 8 | 5 | 4 | 160 | Scheduling maintenance with the electrical section every month | 8 | 5 | 4 | 160 |

**Table 9** Table of Comparison RPN Value Before dan After Improvement

| No | Type of Defects | Before Improvement Average RPN | Categories | After Improvement Average RPN | Categories |
|---|---|---|---|---|---|
| 1 | Tears on the Wrapper | 231 | High | 136,5 | Medium |
| 2 | Porous/Density not Appropriate | 269,5 | High | 126 | Medium |
| 3 | Improper Overlap (2 mm) | 30 | Low | 30 | Low |
| 4 | Wrapper and Tipping Paper not Adhering | 168 | Medium | 140 | Medium |
| 5 | Varying Diameters | 35 | Low | 35 | Low |
| 6 | Varying Lengths of Tipping Paper | 80 | Low | 80 | Low |
| 7 | Absence of Filter | 160 | Medium | 140 | Medium |

Table 9 is the summary of the average RPN before and after the improvements. Defects with the highest initial RPN were porosity or inappropriate density with an RPN value of 269.5. Then, for defects with the second-highest RPN, there were tears in the wrapper with a value of 231. Both types of defects became top priorities for improvement during the implementation

phase. After the improvements, the RPN value for porosity decreased to 126, while tears in the wrapper decreased to 136.5. The implemented improvements proved effective in reducing defects and failures in the production process of PT PID Ongkowidjojo cigarettes, although the resulting decrease was not significant due to some recommended improvements that couldn't be implemented due to budget constraints.

## 4. Conclusions

The research has a limitation, namely the underutilization of gate symbols in FTA. Therefore, for further research, it is hoped that the full potential of gate symbols in FTA can be maximally utilized. Defects with the highest initial RPN were porosity or inappropriate density with an RPN value of 269.5. Then, for defects with the second-highest RPN, there were tears in the wrapper with a value of 231. Both types of defects became top priorities for improvement during the implementation phase. After a two-week implementation of improvements, the RPN value for porosity decreased to 126, while tears in the wrapper decreased to 136.5. The implemented corrective measures were able to reduce the RPN values, although the resulting decrease was not significant. This could be attributed to some recommended improvements that couldn't be implemented due to budget constraints.

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