



Analysis of NPK Phonska Fertilizer Bag Defects Using FTA and FMEA Methods at PT XYZ

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Abstract

This study aims to analyze the defects in NPK Phonska fertilizer bags at PT XYZ, focusing on three main types of defects: torn bags, loose seams, and uneven stitching. From February 2024 to January 2025, a total of 33,159 tons of NPK Phonska bags were found defective, representing 6.639% of the total production. The probability of the defects occurring were calculated as follows: torn bags with a probability of 2.219%, loose seams with 2,003%, and uneven stitching with 1.388%. The research was conducted using Fault Tree Analysis (FTA) and Failure Mode and Effect Analysis (FMEA) methods to identify the root causes and prioritize improvements. FTA was used to trace the causes of defects from a top-down perspective, while FMEA helped assess potential failures and their impacts, assigning Risk Priority Numbers (RPN) to prioritize corrective actions. The findings revealed that human errors, machine malfunctions, and inadequate work environments are the primary causes of the defects. The study concluded that improving the bagging process requires adding operators, implementing a rolling work system, conducting regular machine calibration, increasing workforce capacity to meet production deadlines, and ensuring a safe working environment. The recommendations aim to reduce defect rates and enhance productivity in the warehouse.

Introduction

Indonesia, as an agrarian country, places significant attention on the sustainability of the agricultural sector, which plays a crucial role in the national economy. This sector contributes significantly to economic stability and the welfare of society, with a large portion of the population depending on agriculture (Dewi et al., 2022; Salendu, 2021; Woodhill et al., 2022; Hariram et al., 2023). The fertilizer industry, where many companies produce fertilizers such as PT XYZ, is vital for Indonesia's agricultural sector. PT XYZ produces various types of fertilizers, including NPK Phonska, to support national agricultural productivity.

However, at PT XYZ, particularly in the Phonska IV warehouse, defects in fertilizer bags often occur during the storage and bagging processes. From February 2024 to January 2025, a total of 33,159 tons, or 6.639%, of NPK Phonska bags were found defective, exceeding the company's tolerance limit of 0.240%. The defects found include torn bags, loose seams, and uneven stitching, which reduce the operational productivity of the warehouse.

To address this issue, a study was conducted using Fault Tree Analysis (FTA) and Failure Mode and Effect Analysis (FMEA) methods (Hidayat & Kholil, 2018; Iriani & Mulyani, 2020; Wessiani & Yoshio, 2018; Whiteley et al., 2016; Cristea & Constantinescu, 2017). FTA is a top-down approach used to identify the root causes of failure (Wicaksono & Yuamita,

2022), while FMEA is a proactive risk assessment technique used to analyze potential failures and provide improvement suggestions based on the highest RPN values (Priambodo & Nursanti, 2021). This study is expected to assist PT XYZ in reducing defect rates and providing suggestions for improvements in the storage and bagging processes.

Warehouse and Bagging

A warehouse functions as a storage place for various types of products, both in large and small quantities, for a specific period from the time the products are produced until they are needed by customers or workstations in the production process. As part of the production system, the warehouse is responsible for storing goods until they are retrieved according to the production schedule (Yerlikaya & Arikan, 2024; Lewczuk, 2021; Buzu, 2021). An optimal warehouse system must be able to utilize storage space effectively, thereby improving space efficiency and preventing product pileups due to the warehouse's limited capacity (Fadhilah et al., 2022). Bagging in warehousing is the process of packaging products into bags or specific containers, aimed at facilitating storage, transportation, and distribution of goods. Furthermore, a well-designed bagging system can accelerate the loading and unloading process and ensure that the product quality is maintained during storage in the warehouse (Sied, 2024; Ou et al., 2024; Rianmora et al., 2024; Yusifli, 2022).

Quality Control

According to Syarifah Nazia et al. (2023), quality is a measure of a product or service from the consumer's subjective point of view. The quality of a product produced by a company is determined by certain established measures and standards. If the product does not meet these measures or standards, it is considered defective or damaged. Even if the company has carried out the production process well, products that do not meet the set standards are often still found, where failures in the production process can be influenced by various factors. To prevent potential damage during the production process, companies need to implement more optimal product quality control activities (Shiyamy et al., 2021). Well-executed quality control has a positive impact on the quality of the products produced by the company. The quality of the products produced is determined by various specific measures and characteristics. Product quality control plays a vital role in efforts to improve and enhance product quality, which is a determining factor in the rapid or slow development of a company (Syarifah Nazia et al., 2023; Niyi Anifowose et al., 2022; Chukwunweike et al., 2024; Abdallah et al., 2021).

Root Cause Analysis

Root Cause Analysis (RCA) focuses on tracing the root cause of a problem. This process is conducted by investigating the origin and the factors that trigger the occurrence of the issue. The goal is to improve the process by identifying the failure points in previous handling and the reasons why the problem was not detected earlier (Antony & Grupta, 2019). Additionally, RCA aims to formulate solutions or recommendations to prevent the recurrence of similar errors in the future (Basuki et al., 2023). The 5-Whys method is used to investigate the primary cause of a problem or deviation that occurs in the production process. The fundamental principle of this analysis is to construct a statement about the existing situation, then ask "why" that event occurred. The answer to the first question serves as the basis for the second question, and this process is repeated until the root cause of the issue is identified. The purpose of repeating these questions is to delve deeper into the cause-and-effect relationships, thereby uncovering the underlying problem that needs to be addressed. The 5-Whys analysis helps in identifying the root cause of the issue and clarifies the relationship between various contributing factors to the problem (Susendi et al., 2021; Okes, 2019; Gangidi, 2019).

Fault Tree Analysis

One of the tools used to trace the causes of failure is Fault Tree Analysis (FTA). This method applies a top-down approach, where the analysis begins from the highest level of the system and is then traced downward. Since FTA is part of system analysis, it is important to first understand the concept of system analysis. A system itself consists of a collection of interacting objects that work together to achieve a specific goal. Various system analysis methods are used to identify and analyze errors occurring within a system (Susilo et al., 2020; Selby & Basili, 1991; Söderström, 2018). In this analysis, logic gates are used to represent conditions that can trigger failure, either individually or as a combination of various factors. The construction of FTA involves two main types of logic gates: the AND gate and the OR gate (Arman et al., 2022).

Cut Set Method

According to (Djamal & Azizi, 2015), the Cut Set method is a technique used to identify a list of failure events that could lead to a top event (the primary event). Meanwhile, the Minimum Cut Set is a collection of minimal conditions sufficient to trigger the occurrence of the top event. If all the events in the Minimum Cut Set occur, the main failure will take place. The calculation in Fault Tree Analysis (FTA) is used to determine the probability of the top event occurring. In probability calculations, only the total number of successful processes and the number of process failures are required. This calculation can be expressed with the following formula:

$$P_F = \left(\frac{F}{S+F} \right) \dots \dots \dots (1)$$

$$S = \left(\frac{S_1+S_2+S_3+\dots+S_n}{n} \right) \dots \dots \dots (2)$$

$$F = \left(\frac{F_1+F_2+F_3+\dots+F_n}{n} \right) \dots \dots \dots (3)$$

Description:

S = Number of successful products

F = Frequency of occurrence

P_F = Probability of failure

Next, calculate the probability of each event in each gate according to Ericson in (Nabilah & Sucita, 2022):

For the OR gate, the probability of each event is calculated by addition and subtraction.

a. For 2 inputs

$$P = P_A + P_B \dots \dots \dots (4)$$

$$P = P_A + P_B - (P_A * P_B) \dots \dots \dots (5)$$

b. For more than 2 inputs

$$P = (P_A + P_B + P_C) - (P_{AB} + P_{AC} + P_{BC}) + (P_{ABC}) \dots \dots \dots (6)$$

For the AND gate, the probability of each input is multiplied by each other. If there are two or more inputs, the calculation method remains the same, which is to multiply all the input probabilities together.

$$P = P_A * P_B \dots \dots \dots (7)$$

Failure Mode and Effects Analysis

The FMEA (Failure Mode and Effect Analysis) method is a proactive risk assessment technique widely used in industries to identify and analyze potential failures in a product or process. Failure Mode refers to the type of failure that could occur, while Effect Analysis focuses on the possible impacts resulting from that failure. FMEA aims to detect and evaluate all potential failures in both design and production processes before the product is completed. In general, there are two types of FMEA: Design FMEA, which focuses on analyzing failures in product design, and Process FMEA, which examines potential failures in the production process. This method is used to determine preventive actions to reduce or eliminate failure risks, especially for those with the highest priority (Hisprastin & Musfiroh, 2020). According to (Prasetya et al., 2021), FMEA is a method used to analyze potential failures in systems, designs, processes, or services. This approach involves scoring each failure mode based on three main aspects: occurrence rate, severity level, and detection level. Through this assessment, risks can be identified, and preventive measures can be taken to minimize the potential impact.

Methods

The research was conducted at the PT XYZ in particular at the Warehouse, and Bagging Section of Phonska IV facility due to the requirement of discovery and elimination of defects sources in NPK Phonska bags of fertilizer. The study was carried out between February 2025, when the study was initiated, and the end of the data collection period, covering the entire data collection span on operational and quality control variables. The three major kinds of defect caused in the packaging process targeted in the study are torn bags, loose seams and uneven stitching. The defects were not only scrutinized as independent events; they were analyzed as system products of intricate interplays of human, mechanical and environmental factors. The methodological framework uses Fault Tree Analysis (FTA) and Failure Mode and Effect Analysis (FMEA) as the investigational framework, which is supplemented by Root Cause Analysis (RCA) to identify the corrective actions that will be effective.

The data collection was started with the first-hand observations of bagging processes and examination of the defect logs which have been registered by the quality control department. To every month was tallied the total tonnage of bagged fertilizer, and the number of associated defects, which led to twelve months worth of data of process output and quality detriments. The data was used empirically as a foundation on which to model incidences of defects and pursue its origins. The FTA model conceptualized bagging defects as top events and as such the research modelled the bagging defects as being functionally dependent on discrete and other observable root causes also in the FTA conceptualized as basic events. The methodology serves to assure that the study begins with an empirically anchored point of departure, and with loyalty to the facts of the dynamics of industrial production.

After determining the best events, the technique of Root Cause Analysis was used where 5 Whys was applied to find out most immediate and frequent contributors to every type of defect. To obtain the insights of practitioners and triangulate the observations, the interviews with operators and supervisors, and QC members were organized. Use of the 5 whys technique allowed the study to dig deeper into the anomalies, in order to outline causal chains and discover that the top contributors involved operator actions (e.g., rushing, not being attentive), equipment conditions (e.g., calibration problems, malfunctions), and environment conditions (e.g., being devoid of physical safety barriers). This was put down in simple forms of events that would fill the branches of diagrams FTA.

After defining the fault tree structure, efforts were directed towards determining the probability of occurrence of a basic event through utilization of the probabilistic modeling. Occurrence frequencies were obtained through daily measurements over a 12 months period

and the average frequency of each event was then normalized by the total monthly production volume to produce probability values. These event probabilities formed the inputs to the calculation of probability of each of the top event using Boolean logic in the fault trees. Both the original fault trees and the reduced trees obtained using Minimal Cut Set approach were analyzed separately by performing separate calculations since the Minimal Cut Set approach makes the logical paths less complicated but still retains the important risk relationships. The given dual-modeling allowed the analysis to focus both on real production dynamics and on worst-case theoretical defect probabilities.

The second methodological element, which was used, was the implementation of Failure Mode and Effect Analysis to assess the seriousness, frequency and capability of detecting the identified failure mode. The severity scores were reflected on the estimated operation and financial effect of each type of defect whereas the occurrence scores were based on the estimates of frequency using the FTA calculations. Detecting scores were evaluated by consulting the quality control officers, depending on how well the existing systems of monitoring and controlling abide by it. These three indices were multiplied to get the Risk Priority Number (RPN) of each mode of failure, which gave a numerical value of risk, which could enable the researchers to prioritize failure modes and develop a basis of corrective action prioritization.

The combination of FTA and FMEA offered supporting capabilities: FTA allowed tracing the occurrence of basic failure upwards into serious defects in a systematic, top-down manner; FMEA ranked failure modes in terms of severity and detectability on a bottom-up basis. The combination of two methods helped to make sure that not only the structure of the system vulnerabilities, but also their operational importance was completely covered. The formal successive application of RCA, FTA and FMEA enabled a systematic triangulation to be attained; hence recommendations were not only analytically sound but were also empirically based in the actual realities. The methodology is therefore both very diagnostic and operationally relevant and ensures that PT XYZ has a solid ground to commence specific quality improvement initiatives.

Results and Discussion

The data on the number of bagging events was obtained from the NPK Phonska fertilizer bagging records at the Phonska IV warehouse from February 2024 to January 2025. The following data represents the total number of NPK Phonska fertilizer bags bagged at the Phonska IV warehouse of PT XYZ. There are three types of defects that occurred in the NPK Phonska fertilizer bags, where the products produced did not meet the standards set by the company. The types of defects are torn bags, loose seams, and uneven stitching.

Table 1. Total bagging and number of defects data

No	Month	Total Bagging (Per Ton)	Defects Products (Per Ton)	Good Products (Per Ton)
1	February	38.199	2.467	35.732
2	March	26.614	1.924	24.690
3	April	35.353	2.493	32.860
4	May	24.683	1.752	22.931
5	June	22.359	1.589	20.770
6	July	49.980	3.217	46.763
7	August	54.189	3.654	50.535
8	September	47.527	3.199	44.328
9	October	38.472	2.512	35.960
10	November	52.608	3.348	49.260

11	December	51.718	3.407	48.311
12	January	57.749	3.597	54.152

Source: Quality Control PT XYZ, 2024

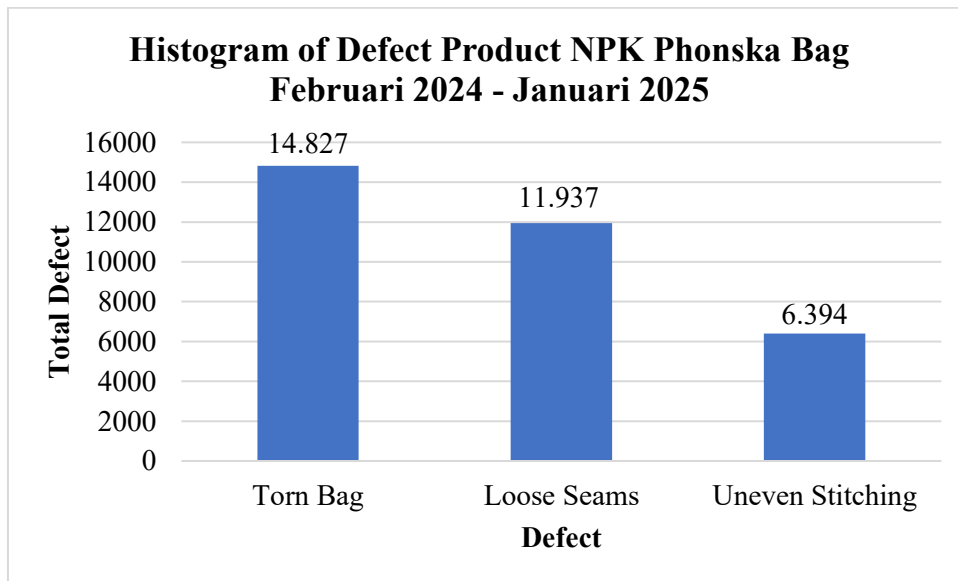


Figure 1. Histogram of Defect Product NPK Phonska Bag Februari 2024 – Januari 2025

Root Cause Analysis

After the top events are identified, the next step is to determine the causes of the defects using Root Cause Analysis (RCA) with the 5 Whys method. The 5 Whys for the defects of torn bags, loose seams, and uneven stitching were obtained through interviews with the QC team. Below are the results of the Root Cause Analysis using the 5 Whys method for the defects of torn bags, loose seams, and uneven stitching.

Table 2. Cause of torn bag defect

Defect Product (Top Event)	Cause of Defect	No	Root Cause (Basic Event)
Torn Bag	<i>Human Error</i>	1	Operator in a hurry
		2	Rough Handling
		3	Lack of supervision
	Work Environment	4	No physical barriers in the storage area

Table 1. Cause of loose seams defect

Defect Product (Top Event)	Cause of Defect	No	Root Cause (Basic Event)
Loose seams	Machine	1	Machine not calibrated
		2	Broken machine
	Work System	3	Production deadline
	<i>Human Error</i>	4	Operator not being careful

Table 2. Cause uneven stitching defect

Defect Product (Top Event)	Cause of Defect	No	Root Cause (Basic Event)
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Uneven stitching	<i>Human Error</i>	1	Lazy operator
		2	Operator not focused
	Machine	3	Thread feeding system blockage
		4	Insufficient lubricant on the sewing machine drive part

Fault Tree Analysis

After identifying the root causes that will serve as the basic events, the daily occurrences of these basic events over a 12-month period were recorded. The data was collected through direct observation and interviews with the quality control department at PT XYZ. The daily error data was then used as the basis for calculating the annual frequency of occurrences, the total annual production, and the annual probability of each basic event. These probability values were subsequently used as input for the fault tree analysis to perform calculations before and after the evaluation phase. Below is an example calculation to obtain the probability of occurrence for the basic event "Operator in a Hurry" (P1)):

Frequency of Occurrence (F) of Operator in Hurry per Day Over One Year (Example in February 2024):

$$F = \frac{f_1 + f_2 + f_3 + \dots + f_{20}}{20}$$

$$F = \frac{191 + 250 + 202 + \dots + 226}{20}$$

$$F = \frac{4.386}{20} = 219 \text{ per day}$$

Average Daily Frequency of Operator in Hurry (F) Over One Year:

$$= \frac{\sum \text{February 2024} + \sum \text{March 2024} + \dots + \sum \text{January 2025}}{12}$$

$$= \frac{219 + 217 + 224 + \dots + 215}{12}$$

$$= \frac{2.595}{12} = 216 \text{ ton/month}$$

Next, the total production for each month will be calculated.

Calculation of total production for each month for the Operator in Hurry event over one year (example for February 2024):

T = Frequency of Occurrence (F) + Number of Successful Products (S)

$$T = 219 + 35.732 = 35.951 \text{ ton / month}$$

Average production quantity for the "Operator in a Hurry" over one year:

$$= \frac{\sum \text{February 2024} + \sum \text{March 2024} + \dots + \sum \text{Bulan January 2025}}{12}$$

$$= \frac{35.951 + 24.907 + 33.084 + \dots + 54.367}{12}$$

$$= \frac{468.887}{12} = 39.074 \text{ ton/month}$$

The next step, after obtaining the average frequency and average total production, is to calculate the probability of occurrence over one year for each basic event.

Probability of failure due to "Operator in a Hurry" over one year:

$$P = \left(\frac{F}{F + S} \right)$$

$$P = \left(\frac{216}{39.074} \right) = 0,00553$$

The following is a recap table showing the average frequency of occurrences, average total production, and the calculated probability of each basic event.

Tabel 3. Probabilities of Root Causes or Basic Events of NPK Phonska Fertilizer Bag Defects from February 2024 to January 2025

No	Basic event (P)	Average Frequency of Occurrences $\left(\frac{f_1 + f_2 + \dots + f_n}{n} \right)$	Average Total Production Tahun (F+S)	Probability of Occurrence $\left(\frac{F}{F + S} \right)$
1	Operator in a hurry	216	39.074	0,00553
2	Rough Handling	216	39.074	0,00554
3	Lack of supervision	216	39.074	0,00553
4	No physical barriers in the storage area	219	39.076	0,00559
5	Machine not calibrated	196	39.053	0,00501
6	Broken machine	196	39.054	0,00502
7	Production deadline	195	39.052	0,00498
8	Operator not being careful	196	39.054	0,00502
9	Lazy operator	137	38.994	0,00350
10	Operator not focused	135	38.992	0,00346
11	Thread feeding system blockage	136	38.993	0,00348
12	Insufficient lubricant on the sewing machine drive part	134	38.992	0,00344

Torn Bag Defect

Based on the Root Cause Analysis using the 5 Whys method, which was created based on interviews with the QC team, the next step is to create a Fault Tree Analysis diagram for each identified top event. Below is the Fault Tree Analysis diagram for the "Torn Bag" defect. This fault tree will also serve as the basis for calculations before the evaluation.

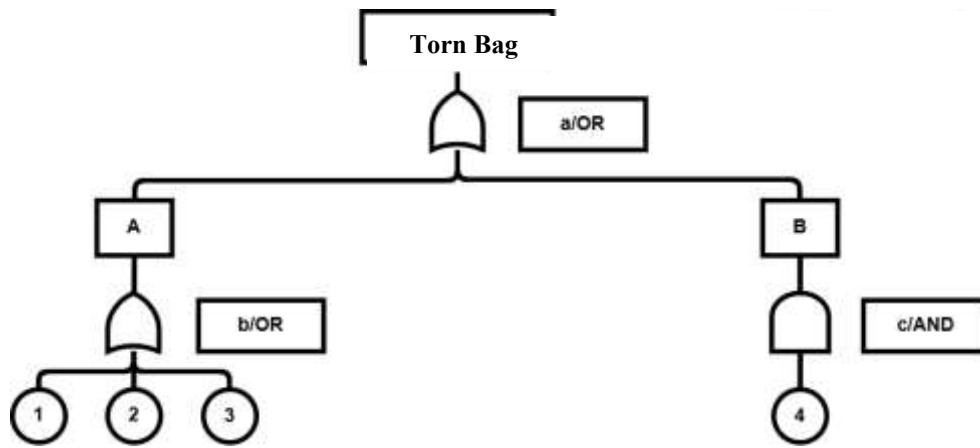


Figure 1. Torn Bag Defect Fault Tree Diagram

Description:

A: Human error

B: Work environment

1: Operator in a hurry

2: Rough handling

3: Lack of supervision

4: No physical barriers in the storage area

Next, the creation of the cut set matrix and minimal cut set for the torn bag defect will be carried out. From this, the equivalent fault tree will be obtained, which will then be used for calculations after the evaluation phase.

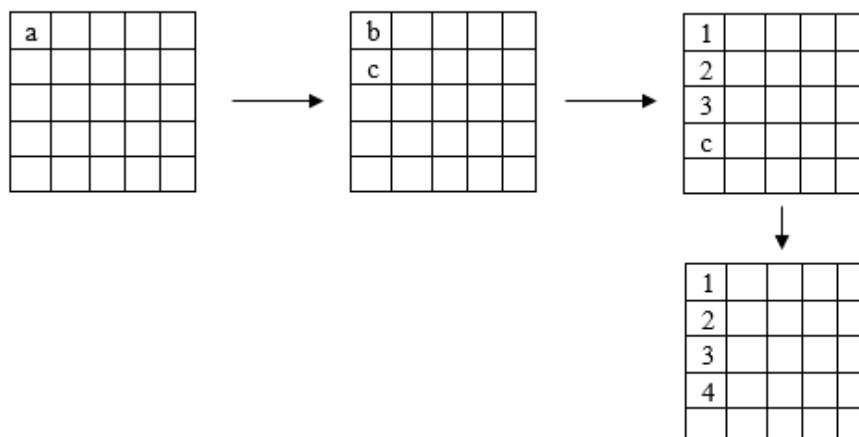


Figure 2. Cut Set Matrix and Minimal Cut Set for Torn Bag Defects

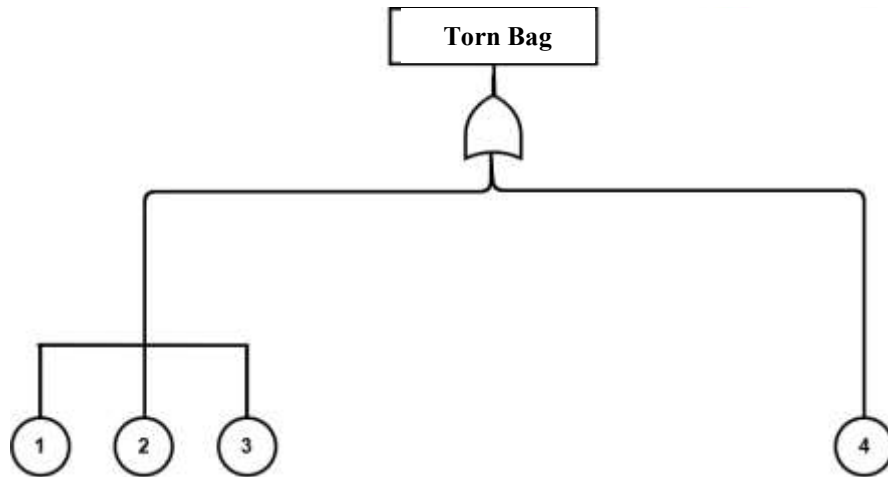


Figure 3. Equivalent Fault Tree Torn Bag Defects

The equivalent fault tree obtained is the simplest and most effective fault tree for identifying the risk of torn bags. In this equivalent fault tree, root causes 1, 2, 3, and 4 form an OR gate. This equivalent fault tree also serves as the basis for calculations after the evaluation phase.

Probability Calculation for Torn Bag Defect

$$P_1 = 0,00553$$

$$P_2 = 0,00554$$

$$P_3 = 0,00553$$

$$P_4 = 0,00559$$

Before evaluation:

$$\begin{aligned} P_A &= (P_1 + P_2 + P_3) - (P_{1.2} + P_{1.3} + P_{2.3}) + (P_{1.2.3}) \\ &= (0,00553 + 0,00554 + 0,00553) - (0,00553 \times 0,00554 + 0,00553 \times 0,00553 + \\ &0,00554 \times 0,00553) + (0,00553 \times 0,00554 \times 0,00553) \\ &= 0,01651 \end{aligned}$$

$$\begin{aligned} P_B &= P_4 \\ &= 0,00559 \end{aligned}$$

$$\begin{aligned} P_T &= (P_A + P_B) - (P_A \times P_B) \\ &= (0,01651 + 0,00559) - (0,01651 \times 0,00559) \\ &= 0,02201 = 2,201\% \end{aligned}$$

After evaluation:

$$\begin{aligned} P_T &= 0,00553 + 0,00554 + 0,00553 + 0,00559 \\ &= 0,02219 = 2,219\% \end{aligned}$$

Based on the calculations performed, the probability of the torn bag defect before evaluation is 2.201% and after evaluation is 2,219%. The figures before the evaluation are smaller because they are calculated using the initial fault tree analysis, which takes into account the interactions between events. This means simultaneous occurrences of basic events are considered, affecting the overall probability calculation. On the other hand, the figures after the evaluation are larger because the calculations use the cut set matrix and minimal cut sets to derive the equivalent fault tree. This equivalent fault tree, used for after evaluation calculations, forms an OR gate that leads directly to the top event. As a result, these figures

are higher since they directly impact the top event without considering interactions among basic events first. Therefore, the after evaluation calculation can also serve as a basis to understand the worst-case scenario for the occurrence of those basic events.

Loose Seams Defect

Based on the Root Cause Analysis using the 5 Whys method, which was created based on interviews with the QC team, the next step is to create a Fault Tree Analysis diagram for each identified top event. Below is the Fault Tree Analysis diagram for the "Loose Seams" defect.

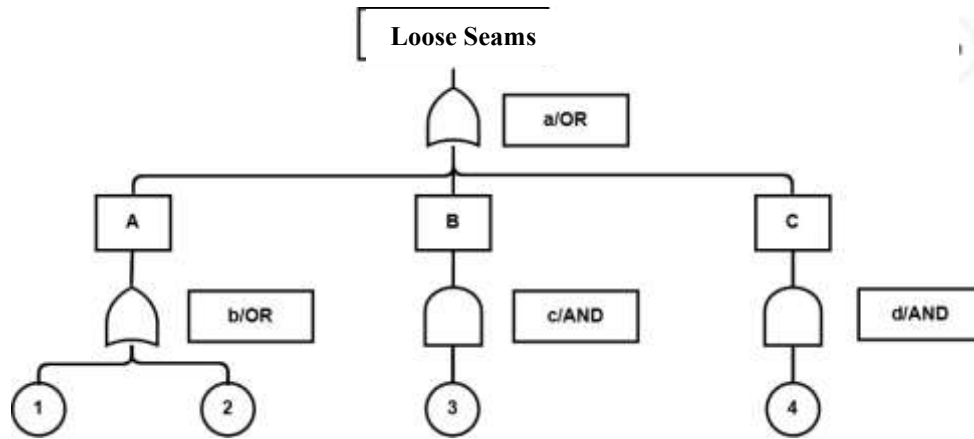


Figure 4. Loose Seams Defect Fault Tree Diagram

Description:

A: Machine

B: Work system

C: Human error

1: Machine not calibrated

2: Broken machine

3: Production deadline

4: Operator not careful

Next, the creation of the cut set matrix and minimal cut set for the torn bag defect will be carried out. From this, the equivalent fault tree will be obtained, which will then be used for calculations after the evaluation phase.

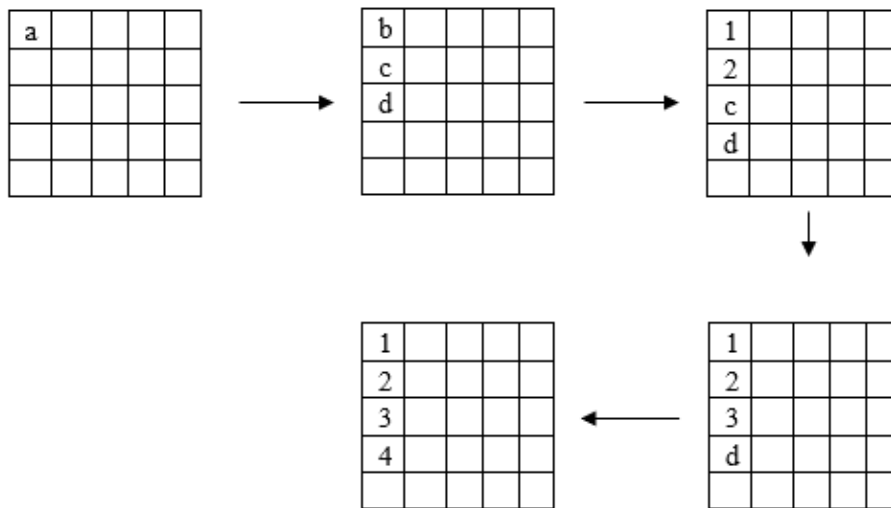


Figure 5. Cut Set Matrix and Minimal Cut Set for Loose Seams Defects

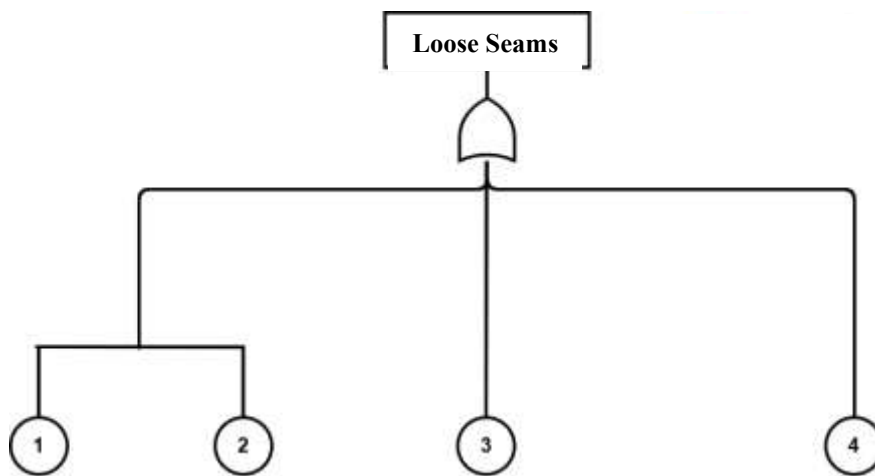


Figure 6. Equivalent Fault Tree Loose Seams Defects

The equivalent fault tree obtained is the simplest and most effective fault tree for identifying the risk of loose seams. In this equivalent fault tree, root causes 1, 2, 3, and 4 form an OR gate. This equivalent fault tree also serves as the basis for calculations after the evaluation phase.

Probability Calculation for Loose Seams Defect

$$P_1 = 0,00501$$

$$P_2 = 0,00502$$

$$P_3 = 0,00498$$

$$P_4 = 0,00502$$

Before evaluation:

$$\begin{aligned} P_A &= (P_1 + P_2) - (P_1 \times P_2) \\ &= (0,00501 + 0,00502) - (0,00501 \times 0,00502) \\ &= 0,01000 \end{aligned}$$

$$\begin{aligned} P_B &= P_3 \\ &= 0,00498 \end{aligned}$$

$$P_C = P_4$$

$$= 0,00502$$

$$\begin{aligned}
 P_T &= (P_A + P_B + P_C) - (P_{A,B} + P_{A,C} + P_{B,C}) + (P_{A,B,C}) \\
 &= (0,01000 + 0,00498 + 0,00502) - (0,01000 \times 0,00498 + 0,01000 \times 0,00502 + \\
 &\quad 0,00498 \times 0,00502) + (0,01000 \times 0,00498 \times 0,00502) \\
 &= 0,01988 = 1,988\%
 \end{aligned}$$

After evaluation:

$$\begin{aligned}
 P_T &= 0,00501 + 0,0502 + 0,0498 + 0,00502 \\
 &= 0,02003 = 2,003\%
 \end{aligned}$$

Based on the calculations performed, the probability of the loose seams defect before evaluation is 1,988% and after evaluation is 2,003%. The figures before the evaluation are smaller because they are calculated using the initial fault tree analysis, which takes into account the interactions between events. This means simultaneous occurrences of basic events are considered, affecting the overall probability calculation. On the other hand, the figures after the evaluation are larger because the calculations use the cut set matrix and minimal cut sets to derive the equivalent fault tree. This equivalent fault tree, used for after evaluation calculations, forms an OR gate that leads directly to the top event. As a result, these figures are higher since they directly impact the top event without considering interactions among basic events first. Therefore, the after evaluation calculation can also serve as a basis to understand the worst-case scenario for the occurrence of those basic events.

Uneven Stitching Defect

Based on the Root Cause Analysis using the 5 Whys method, which was created based on interviews with the QC team, the next step is to create a Fault Tree Analysis diagram for each identified top event. Below is the Fault Tree Analysis diagram for the "Uneven Stitching" defect.

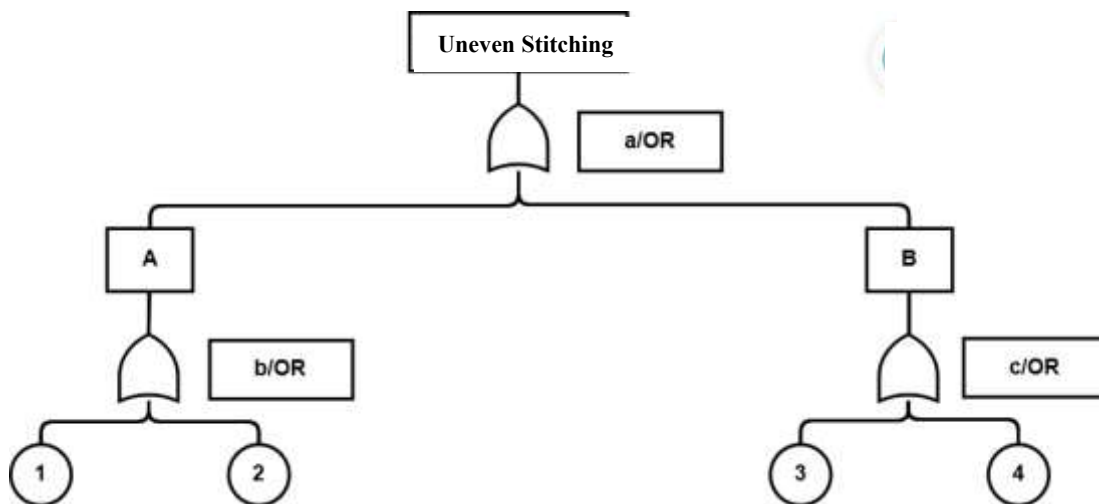


Figure 7. Uneven Stitching Defect Fault Tree Diagram

Description:

A: Human error

B: Machine

1: Lazy operator

2: Operator not focused

3: Thread feeding system blockage

4: Insufficient lubricant on the sewing machine drive part

Next, the creation of the cut set matrix and minimal cut set for the torn bag defect will be carried out. From this, the equivalent fault tree will be obtained, which will then be used for calculations after the evaluation phase.

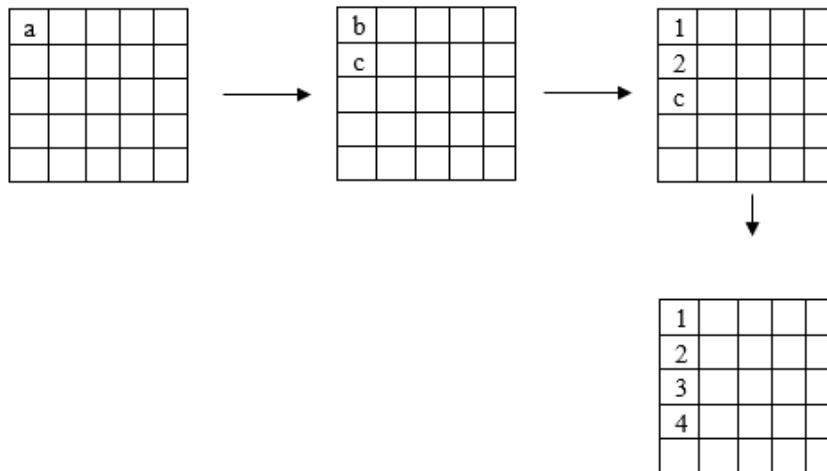


Figure 8. Cut Set Matrix and Minimal Cut Set for Uneven Stitching Defects

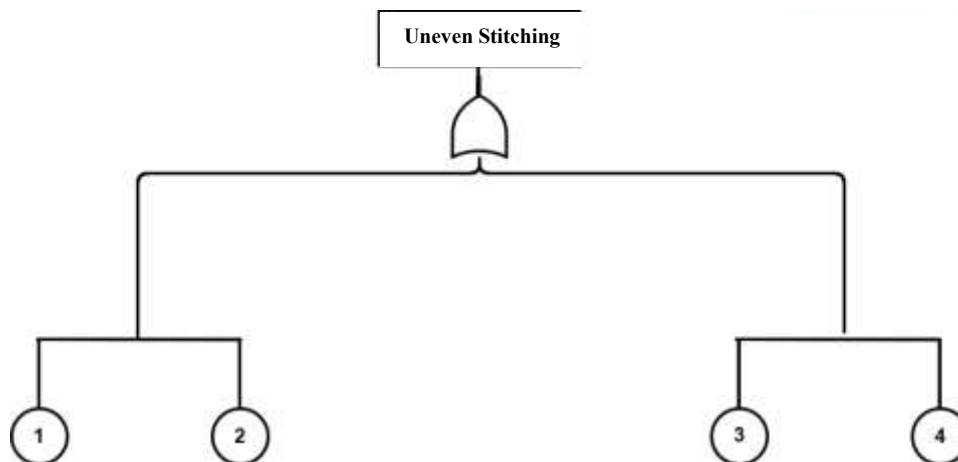


Figure 9. Equivalent Fault Tree Uneven Stitching Defects

Probability Calculation for Uneven Stitching Defect

$$P_1 = 0,00350$$

$$P_2 = 0,00346$$

$$P_3 = 0,00348$$

$$P_4 = 0,00344$$

Before evaluation:

$$\begin{aligned} P_A &= (P_1 + P_2) - (P_1 \times P_2) \\ &= (0,00350 + 0,00346) - (0,00350 \times 0,00346) \\ &= 0,00695 \end{aligned}$$

$$\begin{aligned} P_B &= (P_3 + P_4) - (P_3 \times P_4) \\ &= (0,00348 + 0,00344) - (0,00348 \times 0,00344) \end{aligned}$$

$$= 0,00691$$

$$P_T = (P_A + P_B) - (P_A \times P_B)$$

$$= (0,00695 + 0,00691) - (0,00695 \times 0,00691)$$

$$= 0,01381 = 1,381\%$$

After evaluation:

$$P_T = 0,00350 + 0,00346 + 0,00348 + 0,00344$$

$$= 0,01388 = 1,388\%$$

Based on the calculations performed, the probability of the uneven stitching defect before evaluation is 1,381% and after evaluation is 1,388%. The figures before the evaluation are smaller because they are calculated using the initial fault tree analysis, which takes into account the interactions between events. This means simultaneous occurrences of basic events are considered, affecting the overall probability calculation. On the other hand, the figures after the evaluation are larger because the calculations use the cut set matrix and minimal cut sets to derive the equivalent fault tree. This equivalent fault tree, used for after evaluation calculations, forms an OR gate that leads directly to the top event. As a result, these figures are higher since they directly impact the top event without considering interactions among basic events first. Therefore, the after evaluation calculation can also serve as a basis to understand the worst-case scenario for the occurrence of those basic events.

Failure Mode and Effects Analysis

According to (Prasetya et al., 2021), FMEA is a method used to analyze potential failures in systems, designs, processes, or services. This approach involves assigning scores to each failure mode based on three main aspects: occurrence, severity, and detection. Through this assessment, risks can be identified, and preventive actions can be taken to minimize the potential impact. The Risk Priority Number (RPN) for each failure mode is calculated by multiplying the Severity (S), Occurrence (O), and Detection (D) of each failure mode. Each value in the calculation of Severity (S), Occurrence (O), Detection (D), and the Risk Priority Number (RPN) was obtained through interviews and brainstorming sessions with the quality control team of PT XYZ.

Severity

Based on the three identified types of defects, the impact or effects caused by each defect can be analyzed. Severity refers to the extent of the impact resulting from a failure. The severity scale ranges from 1 to 10, where a score of 1 indicates a negligible or minor negative impact, while a score of 10 represents a very high or critical negative impact on the final product. The severity values were obtained through interviews and brainstorming sessions with the quality control team at PT XYZ.

Tabel 4. Severity (S)

Potential Failure Modes	Potential Effect of Failure	S
Torn Bag	It results in increased costs for procuring additional bags, reduces productivity due to the need for rebagging torn bags, and causes environmental contamination in the warehouse area as fertilizer spills from the torn bags.	8
Loose Seams	It results in increased costs for procuring additional thread and bags if the bags are already damaged. It lowers productivity due to the need for restitching and rebagging	7

	bags with loose seams. It also causes the warehouse to become dirty as fertilizer spills from the loose stitches.	
Uneven Stitching	It leads to the need for additional costs to procure thread and bags if the damaged bags can no longer be used. It reduces productivity due to the need for additional stitching on unfinished sections or restitching if necessary, as well as rebagging for bags with uneven stitching. It also results in a dirty warehouse environment as fertilizer can spill out through the uneven stitches.	6

Occurrence

The potential cause of the resulting effect is derived from the basic events identified using the Fault Tree Analysis (FTA) method. Occurrence refers to the likelihood of a failure occurring. The occurrence rating is determined through interviews with the Quality Control department to assess how frequently the specific causes of failure occur.

Tabel 5. Occurrence (O)

Potential Failures Modes	Potential Effect of Failure	Potential Cause	O
Torn Bag	It results in increased costs for procuring additional bags, reduces productivity due to the need for rebagging torn bags, and causes environmental contamination in the warehouse area as fertilizer spills from the torn bags.	Operator in a hurry Rough Handling Lack of supervision No physical barriers in the storage area	8
Loose Seams	It results in increased costs for procuring additional thread and bags if the bags are already damaged. It lowers productivity due to the need for restitching and rebagging bags with loose seams. It also causes the warehouse to become dirty as fertilizer spills from the loose stitches.	Machine not calibrated Broken machine Production deadline Operator not being careful	7
Uneven Stitching	It leads to the need for additional costs to procure thread and bags if the damaged bags can no longer be used. It reduces productivity due to the need for additional stitching on unfinished sections or restitching if necessary, as well as rebagging for bags with uneven stitching. It also results in a dirty warehouse environment as fertilizer can spill out through the uneven stitches.	Lazy operator Operator not focused Thread feeding system blockage Insufficient lubricant on the sewing machine drive part	6

Detection

Based on the identification of the potential causes of the resulting effects, the current controls that can be implemented by workers to minimize the risk of defects can be determined. Detection is used to assess how difficult it is to detect the failure for quality control purposes. The detection scale ranges from 1 to 10.

Tabel 6. Detection (D)

Potential Failures Modes	Potential Cause	Current Control	D
Torn Bag	Operator in a hurry Rough Handling	Supervision is carried out during the process	6

	Lack of supervision No physical barriers in the storage area	Warnings are issued Physical barriers are provided between the fertilizer and heavy equipment	
Loose Seams	Machine not calibrated Broken machine Production deadline Operator not being careful	Regular machine calibration is conducted Machine inspections are performed Warnings are issued	5
Uneven Stitching	Lazy operator Operator not focused Thread feeding system blockage Insufficient lubricant on the sewing machine drive part	Warnings are issued Machine inspections are conducted by the operator	4

After obtaining the values of Severity (S), Occurrence (O), and Detection (D) for each failure mode, the next step is to calculate the Risk Priority Number (RPN) by multiplying the Severity (S), Occurrence (O), and Detection (D) values of each failure mode.

Table 7. Risk Priority Number (RPN)

Failure Modes	Failure Effect	S E V	Potential Cause	O C C	Current Control	D E T	RPN
Torn Bag	It results in increased costs for procuring additional bags, reduces productivity due to the need for rebagging torn bags, and causes environmental contamination in the warehouse area as fertilizer spills from the torn bags.	8	Operator in a hurry Rough Handling Lack of supervision No physical barriers in the storage area	8	Supervision is carried out during the process Warnings are issued Physical barriers are provided between the fertilizer and heavy equipment	6	384
Loose Seams	It results in increased costs for procuring additional thread and bags if the bags are already damaged. It lowers productivity due to the need for restitching and rebagging bags with loose seams. It also causes the warehouse to become dirty as fertilizer spills from the loose stitches.	7	Machine not calibrated Broken machine Production deadline Operator not being careful	7	Regular machine calibration is conducted Machine inspections are performed Warnings are issued	5	245
Uneven Stitching	It leads to the need for additional costs to procure thread and bags if the damaged bags can	6	Lazy operator Operator not focused	6	Warnings are issued Machine inspections are	4	144

	no longer be used. It reduces productivity due to the need for additional stitching on unfinished sections or restitching if necessary, as well as rebagging for bags with uneven stitching. It also results in a dirty warehouse environment as fertilizer can spill out through the uneven stitches.		Thread feeding system blockage Insufficient lubricant on the sewing machine drive part		conducted by the operator		
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After calculating the Risk Priority Number (RPN), the causes of process failures leading to product defects can be identified. The defect causes (potential causes) are then ranked based on the highest to lowest RPN values, and improvement recommendations can be provided for each identified cause.

Table 8. Improvement Recommendations

Priority	Potential Failure Modes	Potential Cause	RPN	Recommendation
1	Torn Bag	Operator in a hurry Rough Handling Lack of supervision No physical barriers in the storage area	384	Adding manpower to ensure that operators are not rushed due to production deadlines. Providing training related to operational procedures in warehousing and bagging activities. Conducting supervision while operators are performing their tasks. Installing physical barriers between the fertilizer storage area and heavy equipment.
2	Loose Seams	Machine not calibrated Broken machine Production deadline Operator not being careful	245	Perform routine machine calibration before warehousing and bagging activities begin. Conduct scheduled inspections of machine conditions prior to warehousing and bagging operations. Add manpower to ensure production deadlines are met. Provide a safe and comfortable working environment.
3	Uneven Stitching	Lazy operator Operator not focused Thread feeding system blockage	144	Provide rewards to operators who are active and meet targets without making errors.

		Insufficient lubricant on the sewing machine drive part		<p>Add more operators to prevent fatigue and loss of focus.</p> <p>Maintain workplace cleanliness to prevent dust from entering the thread feeding system.</p> <p>Conduct regular inspections of the thread feeding system before warehousing and bagging activities begin.</p> <p>Establish a periodic machine inspection schedule prior to warehousing and bagging operations.</p>
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The main causes of torn bag defects are human error and the work environment. Human error is caused by operators rushing, rough handling, and lack of supervision, while the work environment is impacted by the absence of physical barriers in the storage area. Based on the probability calculation, the defect probability for torn bags before evaluation is 2.201% and after evaluation is 2,219%. The figures before the evaluation are smaller because they are calculated using the initial fault tree analysis, which takes into account the interactions between events. This means simultaneous occurrences of basic events are considered, affecting the overall probability calculation. On the other hand, the figures after the evaluation are larger because the calculations use the cut set matrix and minimal cut sets to derive the equivalent fault tree. This equivalent fault tree, used for after evaluation calculations, forms an OR gate that leads directly to the top event. As a result, these figures are higher since they directly impact the top event without considering interactions among basic events first. Therefore, the after evaluation calculation can also serve as a basis to understand the worst-case scenario for the occurrence of those basic events.

The main causes of loose stitching defects are the machine, the work system, and human error. The machine is affected by lack of calibration and malfunction, the work system is influenced by production deadlines, and human error occurs due to operators not being careful. Based on the probability calculation, the defect probability for loose stitching before evaluation is 1,988% and after evaluation is 2,003%. The figures before the evaluation are smaller because they are calculated using the initial fault tree analysis, which takes into account the interactions between events. This means simultaneous occurrences of basic events are considered, affecting the overall probability calculation. On the other hand, the figures after the evaluation are larger because the calculations use the cut set matrix and minimal cut sets to derive the equivalent fault tree. This equivalent fault tree, used for after evaluation calculations, forms an OR gate that leads directly to the top event. As a result, these figures are higher since they directly impact the top event without considering interactions among basic events first. Therefore, the after evaluation calculation can also serve as a basis to understand the worst-case scenario for the occurrence of those basic events.

The main causes of uneven stitching defects are human error and machine issues. Human error is caused by lazy or unfocused operators, while machine issues are caused by yarn feeding system blockages and insufficient lubrication in the sewing machine drive system. Based on the probability calculation, the defect probability for uneven stitching before evaluation is 1,381% and after evaluation is 1,388%. The figures before the evaluation are smaller because they are calculated using the initial fault tree analysis, which takes into account the interactions between events. This means simultaneous occurrences of basic events are considered, affecting the overall probability calculation. On the other hand, the figures

after the evaluation are larger because the calculations use the cut set matrix and minimal cut sets to derive the equivalent fault tree. This equivalent fault tree, used for after evaluation calculations, forms an OR gate that leads directly to the top event. As a result, these figures are higher since they directly impact the top event without considering interactions among basic events first. Therefore, the after evaluation calculation can also serve as a basis to understand the worst-case scenario for the occurrence of those basic events.

From the analysis using the FMEA method, it was found that the torn bag defect has the highest RPN value of 384. This defect leads to increased costs for procuring additional bags, reduced productivity due to the need for rebagging, and contamination in the warehouse due to fertilizer spilling from torn bags. The causes of this defect include operators rushing, rough handling, lack of supervision, and the absence of physical barriers in the storage area. Suggested improvements include Adding manpower to ensure that operators are not rushed due to production deadlines, providing training related to operational procedures in warehousing and bagging activities, conducting supervision while operators are performing their tasks, and installing physical barriers between the fertilizer storage area and heavy equipment.

The loose stitching defect has an RPN value of 245. This defect results in increased costs for procuring thread and bags if the bags are damaged, decreased productivity due to resewing and rebagging, and contamination of the warehouse due to fertilizer spilling from the loose stitching. The causes of this defect include uncalibrated or malfunctioning machines, tight production deadlines, and careless operators. Suggested improvements include Perform routine machine calibration before warehousing and bagging activities begin, conduct scheduled inspections of machine conditions prior to warehousing and bagging operations, add manpower to ensure production deadlines are met, and provide a safe and comfortable working environment.

Next, the uneven stitching defect has an RPN value of 144. This defect leads to increased costs for procuring thread and bags if the bags are damaged, reduced productivity due to continued sewing or resewing and rebagging, and contamination in the warehouse from fertilizer spilling out of uneven stitching holes. The causes of this defect are lazy or unfocused operators, yarn feeding system blockages, and missed machine inspection schedules. Suggested improvements include Provide rewards to operators who are active and meet targets without making errors, add more operators to prevent fatigue and loss of focus, maintain workplace cleanliness to prevent dust from entering the thread feeding system, conduct regular inspections of the thread feeding system before warehousing and bagging activities begin, and establish a periodic machine inspection schedule prior to warehousing and bagging operations.

Conclusion

Based on previously obtained data, There are three types of defects in NPK Phonska fertilizer bags at PT Petrokimia. The three identified defects are torn bags, loose stitching, and uneven stitching. The highest percentage probability of defect occurrence is for torn bags, with a value of 2.219%, followed by the probability of loose stitching defects at 2.003%, and finally, the probability of uneven stitching defects at 1.388%. Based on the analysis using the FMEA method improvement proposals were made to reduce and prevent defects in NPK Phonska fertilizer bags. For the torn bag defect, the suggested improvements include adding manpower so that operators are not rushed due to production deadlines, providing training related to operational processes in warehousing and bagging activities, supervising operators while they perform their tasks, and installing physical barriers between the fertilizer storage area and heavy equipment. For the loose stitching defect, the recommended improvements are performing routine machine calibration before warehousing and bagging activities begin,

conducting scheduled inspections of machine conditions prior to these activities, adding manpower to ensure production deadlines are met, and providing a safe and comfortable working environment. For the uneven stitching defect, the proposed improvements include providing rewards to operators who are active and meet targets without making mistakes, increasing the number of operators to prevent fatigue and loss of focus, maintaining workplace cleanliness to prevent dust from entering the thread feeding system, conducting regular inspections of the thread feeding system before warehousing and bagging activities begin, and establishing a periodic machine inspection schedule prior to these operations.

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