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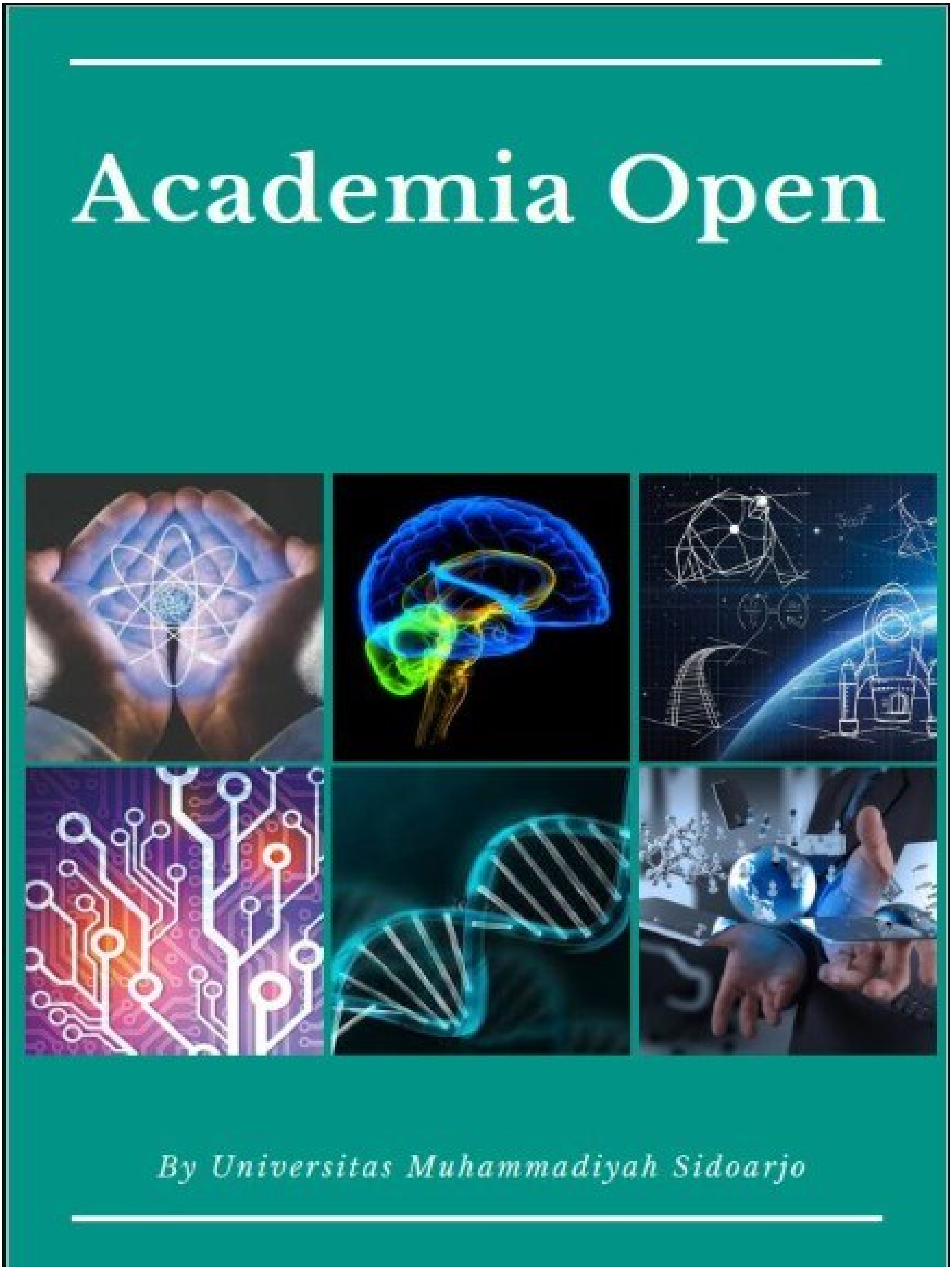

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Integrated FTA and FMEA for HDPE Plastic Bag Defect Reduction

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Abstract

General Background: Quality risk mitigation is essential for maintaining production stability and product conformity in manufacturing industries. **Specific Background:** PT XYZ produces High Density Polyethylene plastic bags in various sizes, with the 15×30 size exhibiting the highest defect rate during January–September 2025, particularly folded, incorrect cutting, asymmetrical cut, and no handle hole defects. **Knowledge Gap:** Previous studies generally applied Fault Tree Analysis (FTA) or Failure Mode and Effect Analysis (FMEA) separately or focused on limited defect types and specific production stages, resulting in less comprehensive defect evaluation. **Aims:** This study aims to systematically identify root causes and determine improvement priorities for dominant defects in 15×30 HDPE plastic bag production through an integrated FTA and FMEA framework. **Results:** FTA identified 15 critical basic events associated with operator control, machine condition, material handling, and maintenance practices. Defect probability values were 7.079% for folded, 9.314% for incorrect cutting, 9.741% for asymmetrical cut, and 6.635% for no handle hole defects. FMEA results showed the highest Risk Priority Number for folded defects (RPN 240), followed by incorrect cutting (RPN 210), asymmetrical cut (RPN 180), and no handle hole (RPN 175). **Novelty:** The study integrates deductive root cause modeling and quantitative risk prioritization within a single analytical structure applied to a specific industrial product size. **Implications:** The proposed actions, including SOP standardization, preventive maintenance, calibration, and operator monitoring, provide structured guidance for systematic defect reduction and sustainable quality management in HDPE plastic bag manufacturing.

Highlights:

- Fifteen critical basic events were mapped across operator, machine, material, and maintenance factors.
- Incorrect cutting and asymmetrical cut showed the largest probability values among dominant nonconformities.
- Risk prioritization placed folded nonconformity at the top improvement rank based on RPN assessment.

Keywords: Fault Tree Analysis, Failure Mode and Effect Analysis, HDPE Plastic Bags, Defect Probability, Risk Priority Number

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Introduction

In increasingly competitive industrial conditions, companies are required to provide optimal handling and maintain high product quality in order to survive and grow. Product quality is a crucial factor for company development, as consumers expect products that are not only free from defects but also capable of delivering value beyond what competitors offer during transactions [1]. To build customer loyalty, companies need to implement effective quality management systems and continuously innovate their product [2]. This effort is essential to improve product standards in the perception of consumers. The objective of quality management is not merely to identify errors in the production process, but rather to prevent errors and minimize product defects [3]. By maintaining consistent product quality, the final output can meet consumer expectations and requirements [4]. This study offers a novel contribution by systematically integrating Fault Tree Analysis (FTA) and Failure Mode and Effect Analysis (FMEA) to address quality defects in HDPE plastic bag production. Unlike previous studies that apply FTA or FMEA separately, this research combines root cause identification and risk prioritization into a single analytical framework. Furthermore, the proposed approach is applied to a specific product size (15×30) in a real industrial setting, providing practical and actionable improvement strategies. This integration enables more comprehensive defect mitigation and supports sustainable quality improvement.

PT XYZ is a manufacturing company that has been operating since 1998 and is engaged in the plastic industry. The company produces various types of plastic bags, including Polypropylene, Polyethylene, and High Density Polyethylene. Among these products, High Density Polyethylene plastic bags have become the company's flagship product due to their high demand for various packaging needs. In line with market demand, the company produces High Density Polyethylene plastic bags in several sizes, namely 15×30, 24×40, 28×48, and 40×67. Although the company has implemented a continuous production system with established operational standards, defects are still found in the production process as a result of imperfections in production activities.

The defects identified include folded products, holes, contamination, incorrect cutting, absence of handle holes, asymmetrical cuts, and uneven color. The variety of defect types indicates that the production process still has potential uncontrolled stages, which may be caused by machine settings, material conditions, or human factors. Among all product sizes, High Density Polyethylene plastic bags size 15×30 exhibit a higher defect rate compared to other sizes. This condition is influenced by the higher production volume due to strong market demand, which increases the probability of defect occurrence. In addition, higher machine operating speeds to meet production targets make it more difficult to control process stability, including temperature, pressure, and plastic sheet positioning, resulting in greater variability in defect occurrence. The following are the defect data of High-Density Polyethylene (HDPE) plastic bags size 15×30 at PT Harapan Sejahtera Karya Utama for the period January–September 2025:

Table 1. Defect Data of High Density Polyethylene Plastic Bags Size 15×30 at PT XYZ January–September 2025

Month	**Total Production (tons)**	**Total Production Defects (tons)**						
		Folded	**Incorrect Cutting**	**No Handle Hole**	**Asymmetrical Cut**	**Holed**	**Contaminated**	**Uneven Color**
January	150	5,03	2,01	1,54	1,01	0,08	0,02	0,03
February	138	4,21	4,04	0,72	1,31	0,09	0,05	0,05
March	150	4,12	3,20	1,32	2,01	0,05	0,03	0,02
April	148	4,41	4,02	1,05	0,31	0,09	0,06	0,04
May	125	4,08	4,13	1,23	1,51	0,04	0,03	0,02
June	143	3,15	3,02	1,18	1,58	0,07	0,07	0,05
July	128	3,01	3,75	1,03	2,03	0,05	0,02	0,03
August	146	4,12	3,11	0,81	2,62	0,03	0,04	0,02
September	150	4,01	3,06	1,21	1,63	0,06	0,05	0,03
Total	**1278**	**36,14**	**30,34**	**10,09**	**14,01**	**0,56**	**0,37**	**0,29**
% Defect		**2,83%**	**2,37%**	**0,79%**	**1,09%**	**0,04%**	**0,02%**	**0,02%**

Based on production data from January to September 2025, four dominant defect types were identified in High Density Polyethylene plastic bags size 15×30, namely folded defects at 2.83 percent, incorrect cutting at 2.37 percent, absence of handle holes at 0.79 percent, and asymmetrical cuts at 1.09 percent. These flaws are frequently present in large numbers, diminishing the product's usefulness and aesthetic value, and are associated with systematically improving machine parameters and operator abilities. In order to help PT XYZ improve their quality and production efficiency, this study focuses on analyzing the causes and control of these four dominant defects.

An investigation into the reasons behind defects in 15×30 High Density Polyethylene plastic bags is necessary in order to resolve these quality issues. To determine the origins of risks and the relationship between causes and effects of failures, one can use fault tree analysis, a deductive technique [5]. One analytical tool that can be utilized to find and track down the origins of production process failures or defects is fault tree analysis. [6]. The method relies on deductive reasoning to identify the root causes, or basic events, of an issue by beginning with the most obvious problem (a defect or failure) and working backwards [7]. Fault Tree Analysis (FTA) helps businesses learn more about the key variables that affect defect occurrences the most [8]. Fault Tree Analysis' strength is in the speed and ease with which it can identify and break down system errors [9]. By allowing qualitative tracing of cause-effect relationships leading to failures, attribute data is used to support the application of Fault Tree Analysis [10]. Also, before products reach customers, Failure Mode and Effect Analysis is employed to find and minimize possible failures in systems, designs, processes, or services [11]. When ranking improvement tasks according to severity, frequency, and detectability, Failure Mode and Effect Analysis is a great tool to use [12]. To examine the recognized risk factors, the Failure Mode and Effects Analysis (FMEA) technique was employed [13].

Previous studies, such as those conducted by [14] ,limited the analysis to only two dominant defect types, thereby not fully capturing all relevant quality dimensions. Meanwhile, research by [15] focused defect analysis on a single process stage along the production line. Therefore, this study has high urgency and novelty by providing a comprehensive analysis that identifies various defect types throughout the entire production process, offering a holistic understanding of defect sources. Through the integration of Fault Tree Analysis and Failure Mode and Effect Analysis, this study is expected to reduce defect levels, improve product quality, enhance production efficiency, and strengthen the competitiveness of PT XYZ in the plastic bag manufacturing industry.

Method

At initial stage of the analysis, primary and secondary data were collected as the basis for data processing and analysis. Primary data were obtained through direct observation of the production process of High-Density Polyethylene (HDPE) plastic bags size 15×30 at PT XYZ, in-depth interviews with relevant personnel, and discussions with production operators and quality control staff. The observations aimed to identify defect types, production flow, machine conditions, and the implementation of operating procedures on the shop floor. Interviews were conducted to explore information related to defect causes, operational constraints, and existing quality control practices.

Secondary data were collected from internal company documentation, including production volume data, defect quantity and defect type records, quality reports, and historical production data for the period January to September 2025. These data were used to identify defect patterns, frequency of occurrence, and dominant defects in HDPE plastic bag products size 15×30. The integration of primary and secondary data provided a comprehensive understanding of the actual production conditions and quality-related problems.

Then, in order to get to the bottom of product defect causes, we used Fault Tree Analysis (FTA) to methodically find causal relationships. Based on ratings for Severity, Occurrence, and Detection, the Risk Priority Number (RPN) was calculated for each defect using Failure Mode and Effect Analysis (FMEA) after the underlying causes had been located. Because it allows for a thorough analysis by merging structured root cause identification with quantitative risk prioritization, the integration of FTA and FMEA was chosen. When it comes to complex manufacturing processes, this integrated method offers a more effective foundation for determining correct action priorities than conventional quality improvement approaches that primarily focus on frequency defect.

We prioritized the improvement recommendations based on the highest RPN values, which were derived from the results of the FTA and FMEA analyses. Product quality, process effectiveness, machine reliability, work methods, and operator competition are the primary areas that would be improved upon by the proposed changes. The production of HDPE plastic bags is expected to experience a decrease in defect rates and a support for long-term quality improvement with this integrated approach. The study used Fault Tree Analysis (FTA) and Failure Mode and Effects Analysis (FMEA) to analyze and solve problems. The flow diagram of these procedures is shown in the following figure :

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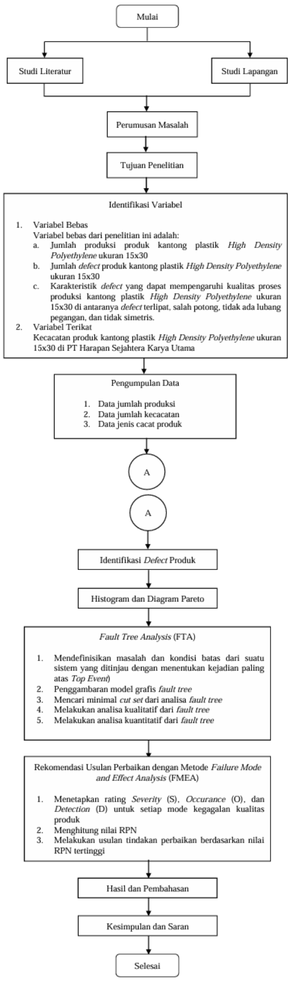

Figure 1. Flowchart

Result and Discussion

A. Checksheets

A data collection sheet used to track an activity within a specific time frame is called a check sheet or an inspection sheet. Table 2 displays the details of the defect data for 15×30 size High-Density Polyethylene (HDPE) plastic bags throughout this time :

Table 2. Production data and production defects checksheet.

Month	Total Production Defects (tons)				Total
	Folded	Incorrect Cutting	No Handle Hole	Asymmetrical Cut	
Januari	5,03	2,01	1,01	1,54	9,59
Februari	4,21	4,04	1,31	0,72	10,28
Maret	4,12	3,20	2,01	1,32	10,65
April	4,41	4,02	0,31	1,05	9,79
Mei	4,08	4,13	1,51	1,23	10,95
Juni	3,15	3,02	1,58	1,18	8,93
Juli	3,01	3,75	2,03	1,03	9,82
Agustus	4,12	3,11	2,62	0,81	10,66
September	4,01	3,06	1,63	1,21	9,91
Total	36,14	30,34	14,01	10,09	90,58

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Month	Total Production Defects (tons)				Total
	Folded	Incorrect Cutting	No Handle Hole	Asymmetrical Cut	
% Defect	39,9%	33,5%	15,5%	11,1%	100,0%
% Cumulative Defect	39,9%	73,4%	88,9%	100%	

Based on the data presented in the table above, the most frequently occurring defect types include folded defects, incorrect cutting, missing handle holes, and asymmetrical cuts. Therefore, these four defect types are determined as the main focus of analysis in this study.

B. Histogram

A histogram or bar chart that shows the degree of "variation in data measurements. The following figure shows the histogram of defect quantity for HDPE plastic bags size 15x30, Januari-September 2025 :

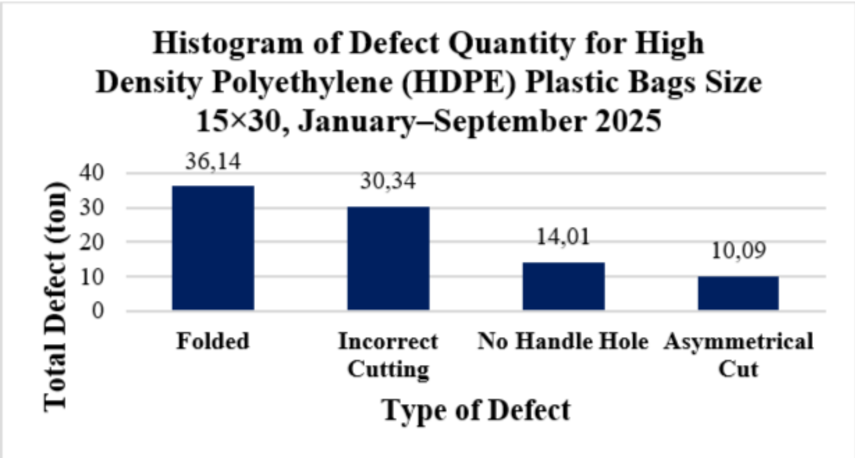

Figure 2. Histogram

C. Pareto Chart

Pareto diagrams are bar graphs that are often used as an interpretation tool to order each type of defect from largest to smallest. The following figure shows the pareto diagram of defect in HDPE plastic bags size 15x30, January – September 2025 :

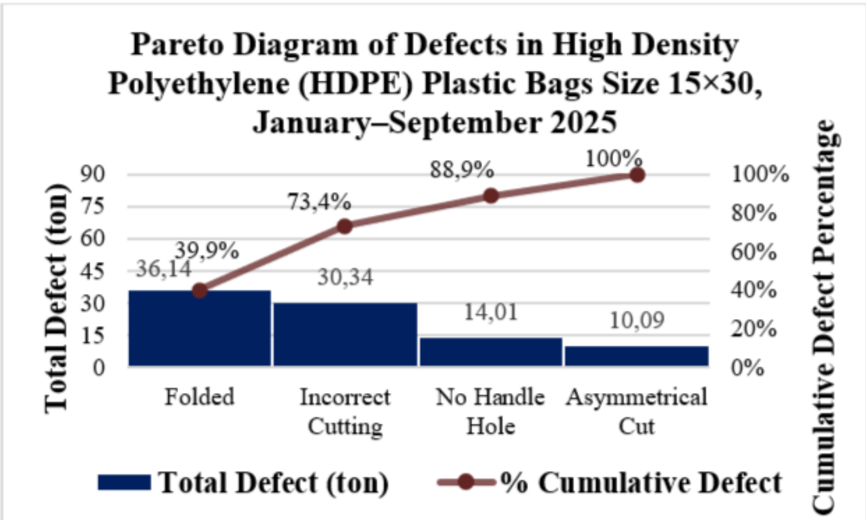

Figure 3. Pareto Diagram

As illustrated in the figure, the most frequent failure events in the production of HDPE plastic bags size 15×30 are folded defects (36,14 tons), incorrect cutting defects (30,34 tons), asymmetrical defects (14,01 tons), and missing handle hole defects (10,09 tons).

D. Fishbone Diagram

The fishbone diagram is used to identify the factors that cause defects. The following are the factors that cause defect :

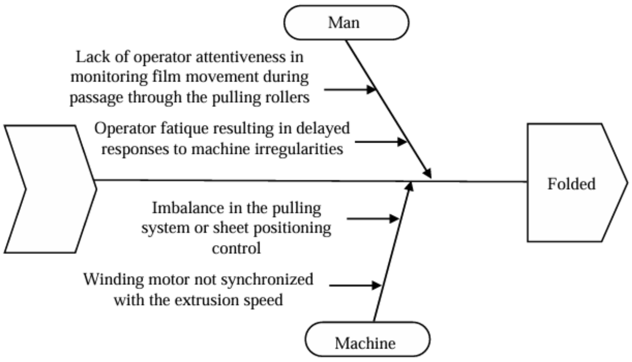

Figure 4. Fishbone Diagram Defect Folded

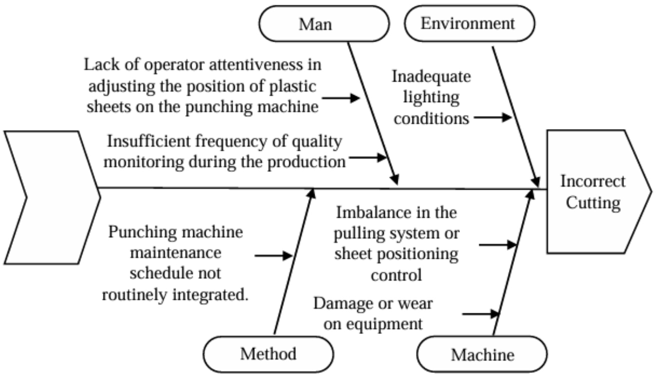

Figure 5. Fishbone Diagram Defect Incorrect Cutting

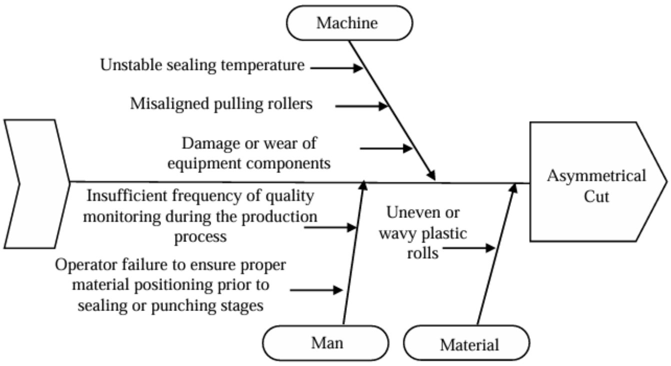

Figure 6. Fishbone Diagram No Handle Hole

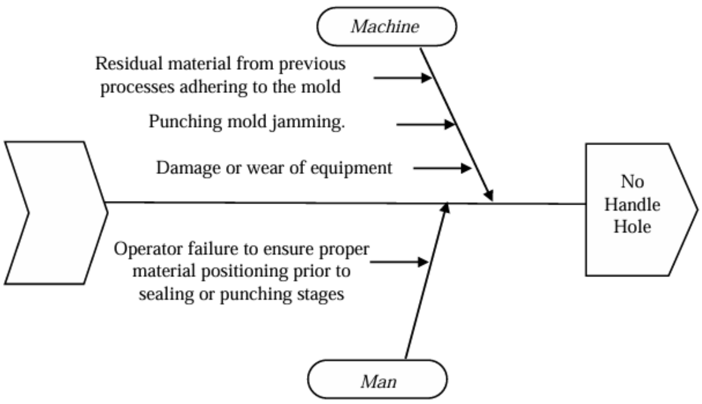

Figure 7. Fishbone Diagram Defect Asymmetrical Cut

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The descriptions of the root causes triggering product defects are summarized as follows:
1. Lack of operator attentiveness in monitoring film movement through pulling rollers.
Insufficient monitoring allows early film folds to go undetected and propagate to subsequent processes, resulting in folded defects in the final product.
2. Operator fatigue causing delayed response to machine irregularities.
Reduced concentration due to fatigue leads to delayed detection of abnormal machine conditions, increasing the risk of production defects.
3. Imbalance in the pulling system or sheet positioning control.
Uneven roller pressure or unstable sheet positioning causes folding and dimensional inaccuracies in the plastic bags.
4. Winding motor not synchronized with extrusion speed.
Mismatch between extrusion and winding speeds creates unstable film tension, leading to folds or film damage.
5. Lack of operator attentiveness in positioning plastic sheets on the punching machine.
Improper sheet alignment results in incorrect cutting and dimensional defects.
6. Insufficient frequency of in-process quality monitoring.
Limited inspection during production delays corrective actions, allowing defects to accumulate.
7. Inadequate lighting conditions.
Poor lighting reduces visibility during cutting operations, increasing the likelihood of misalignment and incorrect cuts.
8. Punching machine maintenance schedule not routinely integrated.
Irregular maintenance reduces machine performance and increases the risk of cutting defects.
9. Operator failure to ensure proper material alignment before sealing or punching.
Misaligned material leads to asymmetrical sealing or misplaced handle holes.
10. Unstable sealing temperature.
Inconsistent temperature results in weak or damaged seals.
11. Misaligned pulling rollers.
Uneven tension across the film causes asymmetrical products.
12. Damage or wear of equipment components.
Worn cutting blades or punching molds reduce precision and product quality.
13. Uneven or wavy plastic rolls.
Irregular rolls disrupt material flow, causing folding and asymmetrical defects.
14. Punching mold jamming.
Mold blockage prevents proper hole formation and smooth cutting.
15. Residual material from previous processes adhering to the mold.
Remaining material interferes with punching accuracy and causes shape defects.

E. Fault Tree Analysis (FTA)

After identifying the root causes or basic events that trigger defects in the production process of High Density Polyethylene (HDPE) plastic bags size 15×30 at PT XYZ, data were obtained regarding the daily occurrence of each root cause over a nine-month period, from January 2025 to September 2025. The number of working days at PT XYZ is 30 days per month. The following presents an example of probability calculation for a root cause in the form of lack of operator attentiveness in monitoring film movement through the pulling rollers (P1) for each month.
Frequency of occurrence (F) of operator inattentiveness in monitoring film movement through the pulling rollers (P1) per day during one month (Example in January 2025):

$$
\begin{aligned}
F &= \frac{f_1 + f_2 + f_{3+\cdots} + f_{30}}{30} \\
&= \frac{1+3+4+1+4+2+3+3+3+1+4+2+4+3+2+\cdots+1}{30} \\
&= \frac{76}{30} \\
&= 2{,}53 \approx 3 \; per\ hari
\end{aligned}
$$

Average daily frequency of operator inattentiveness in monitoring film movement through the pulling rollers over a nine-month period from January to September 2025 :

$$
\begin{aligned}
\bar{F} &= \frac{f_{January} + f_{February} + f_{March} + . \ldots + f_{September}}{9} \\
&= \frac{3+2+3+3+\cdots+3}{9} \\
&= \frac{24{,}00}{9} \\
&= 2{,}67 \approx 3 \; per\ hari
\end{aligned}
$$

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

Calculation of total production for each month for the monitoring film movement through the pulling rollers event over a nine-month period from January to September 2025 (example for January 2025) :

$$T = \text{Frequency of Occurrence (F)} + \text{Number of Successful Products (S)}$$
$$T = 3 + 140{,}41 = 143{,}41 \text{ ton/month}$$

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Average production quantity associated with operator inattentiveness in monitoring film movement through the pulling rollers (P1) over the nine-month period from January to September 2025:

$$\bar{T} = \frac{f_{January} + f_{February} + f_{March} + \ldots + f_{September}}{9}$$
$$= \frac{143{,}41 + 129{,}72 + 142{,}35 + \cdots + 143{,}09}{9}$$
$$= \frac{1211{,}42}{9}$$
$$= 134{,}60 \text{ ton/bulan}$$

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 "Monitoring film movement through the pulling rollers (P1)" over the nine-month period from January to September 2025:

$$P = \left[\frac{\bar{F}}{\bar{T}}\right]$$
$$P = \left[\frac{3}{134{,}60}\right] = 0{,}01981$$

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

Table 3. Probability of Root Causes or Basic Events of Defects in High Density Polyethylene (HDPE) Plastic Bags Size 15×30 January–September 2025

No	Basic Event (P)	Average Frequency of Occurences (F)	Average Total Production	Probability of Occurrence
1	Lack of operator attentiveness in monitoring film movement during passage through the pulling rollers (P1)	3	134,05	0,01981
2	Operator fatique resulting in delayed responses to machine irregularities (P2)	3	134,49	0,01900
3	Imbalance in the pulling system or sheet positioning control (P3)	3	134,49	0,01900
4	Winding motor not synchronized with the extrusion speed (P4)	2	133,94	0,01493
5	Lack of operator attentiveness in adjusting the position of plastic sheets on the punching machine (P5)	2	133,94	0,01493
6	Insufficient frequency of quality monitoring during the production (P6)	3	134,49	0,01900
7	Inadequate lighting conditions (P7)	2	133,94	0,01493
8	Punching machine maintenance schedule not routinely integrated (P8)	2	133,94	0,01493
9	perator failure to ensure proper material positioning prior to sealing or punching stages (P9)	2	133,94	0,01493
10	Unstable sealing temperature (P10)	2	133,94	0,01493
11	Misaligned pulling rollers (P11)	3	134,49	0,01900
12	Damage or wear of equipment components (P12)	2	133,94	0,01493
13	Uneven or wavy plastic rolls (P13)	2	133,94	0,01493
14	Punching mold jamming (P14)	2	133,94	0,01493
15	Residual material from previous processes adhering to the mold (P15)	2	133,94	0,01493

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After identifying the causes of the defects, the next step is to create the Fault Tree Analysis (FTA) diagram for each type of defect.

1. Folded Defect

The defect structure in error analysis serves to identify the minimal combinations of causes that can trigger failures in the production process. By utilizing a fault tree diagram, this method illustrates the logical relationships among the main contributing factors, while the minimal cut set is used to indicate the smallest combination of events that can lead to the occurrence of folded defects. The following figure presents the defect structure for folded defects :

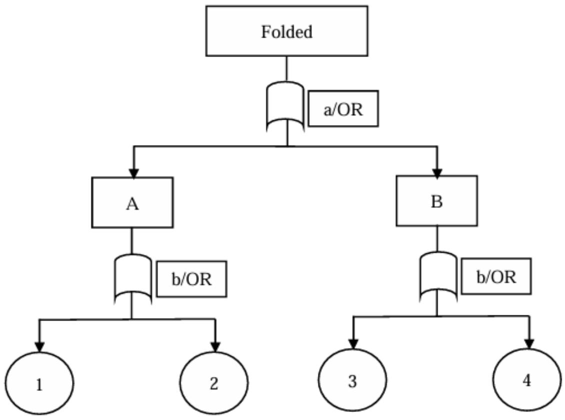

Figure 8. Fault Tree Analysis of Folded Defect

Description :
A : Process control by operators is not optimal
B : Mechanical system performance is not functioning properly
1: Lack of operator attentiveness in monitoring film movement during passage through the pulling rollers
2: Operator fatique resulting in delayed responses to machine irregularities
3: Imbalance in the pulling system or sheet positioning control
4: Winding motor not synchronized with the extrusion speed

Next, the creation of the cut set matrix and minimal cut set for the folded 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.

The cut set matrix derived from the fault tree diagram for the folded defect event is obtained as follows:

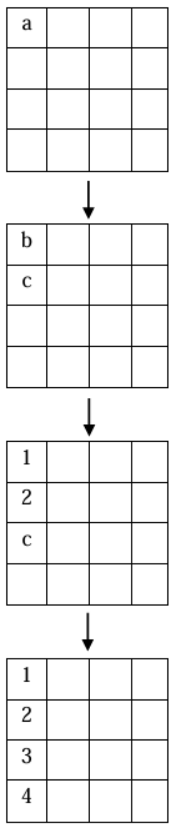

Figure 9. Cut Set Matrix and Minimal Cut Set for Folded Defects

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The following figure presents the equivalent Fault Tree Analysis of the folded defect :

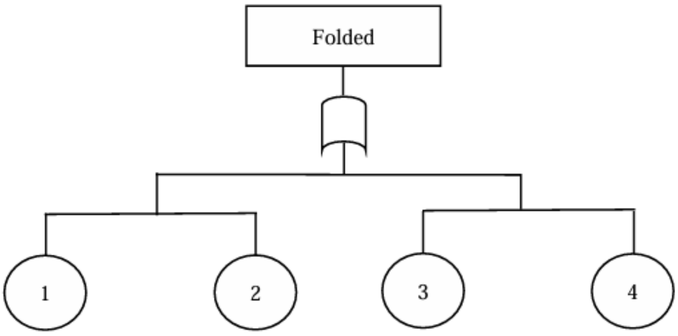

Figure 10. Equivalent Fault Tree Analysis of Folded Defect

The calculation of defect probability is carried out by referring to the fault tree diagram under the initial conditions, that is, before any corrective actions are implemented. The analysis begins with the root-level causal elements and progresses upward to higher levels until the total probability of folded defects is determined. The probability value for each event over a single period is calculated using the data presented in Table.

Probability calculation of folded defects

$P_1 = 0,01981$ $\quad P_3 = 0,01900$

$P_2 = 0,01900$ $\quad P_4 = 0,01493$

$$P_A = (P_1 + P_2) - (P_1 \times P_2)$$
$$= (0,01981 + 0,01900) - (0,01981 \times 0,01900)$$
$$= (0,03881) - (0,00938)$$
$$= 0,03843$$

$$P_B = (P_3 + P_4) - (P_3 \times P_4)$$
$$= (0,01900 + 0,01493) - (0,01900 \times 0,01493)$$
$$= (0,03393) - (0,00028)$$
$$= 0,03365$$

$$P_{Folded} = (P_A + P_B) - (P_A \times P_B)$$
$$= (0,03843 + 0,03365) - (0,03843 \times 0,03365)$$
$$= (0,07208) - (0,000129)$$
$$= 0,07079 = 7,079\%$$

After evaluation :

$T = 0,01981$ $\quad P_{k3} = P_3 = 0,01420$

$P_{k2} = P_2 = 0,01900$ $\quad P_{k4} = P_4 = 0,01338$

$$P_T = P_{K1} + P_{K2} + P_{K3} + P_{K4}$$
$$= 0,01981 + 0,01900 + 0,01900 + 0,01493$$
$$= 0,07274 = 7,274\%$$

Based on the calculations performed, the probability of the loose seams defect before evaluation is 7,079% and after evaluation is 7,274%.

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2. Incorrect Cutting Defect

The following figure presents the defect structure for incorrect cutting defects :

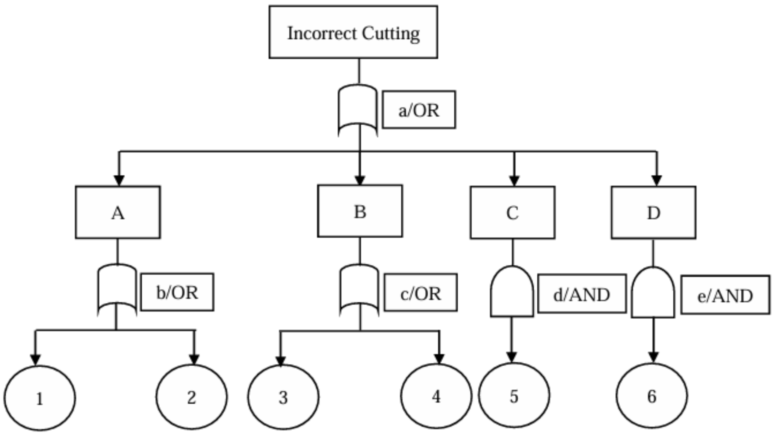

Figure 11. Fault Tree Analysis of Incorrect Cutting Defect

Description :
A : Improper operator settings
B : Suboptimal machine condition
C : Inconsistent maintenance practices
D : Unsupportive work area conditions
1: Lack of operator attentiveness in adjusting the position of plastic sheets on the punching machine
2: Insufficient frequency of quality monitoring during the production
3: Imbalance in the pulling system or sheet positioning control
4: Damage or wear on equipment
5: Punching machine maintenance schedule not routinely integrated
6: Inadequate lighting conditions

The cut set matrix derived from the fault tree diagram for the incorrect cutting defect event is obtained as follows:

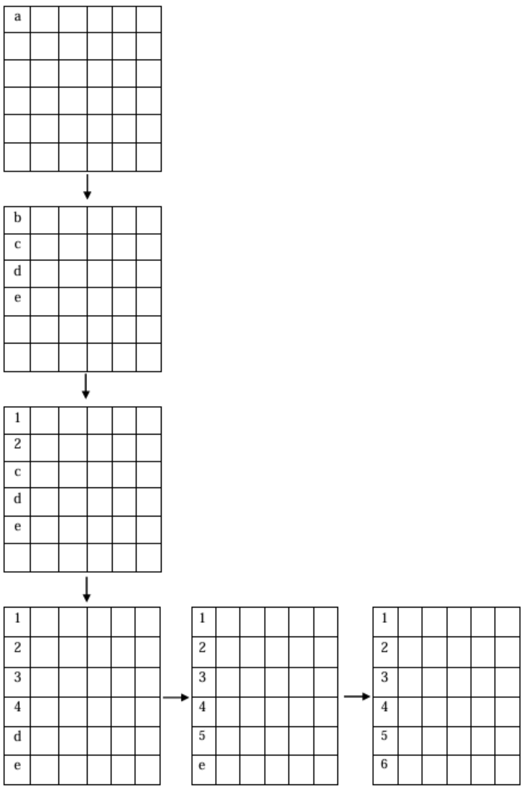

Figure 12. Cut Set Matrix and Minimal Cut Set for Incorrect Cutting Defects

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The following figure presents the equivalent Fault Tree Analysis of the incorrect cutting defect :

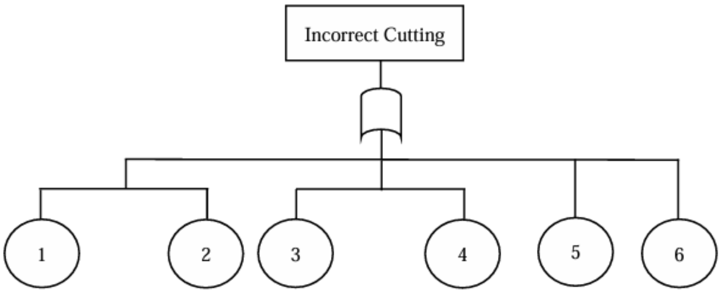

Figure 13. Fault Tree Analysis of Incorrect Cutting Defect

Probability calculation of Incorrect Cutting defects

$P_1 = 0,01493$ $P_4 = 0,01493$

$P_2 = 0,01900$ $P_5 = 0,01493$

$P_3 = 0,01493$ $P_6 = 0,01493$

$P_A = (P_1 + P_2) - (P_1 \times P_2)$

$= (0,01493 + 0,01900) - (0,01493 \times 0,01900)$

$= (0,03393) - (0,00028367)$

$= 0,03365$

$P_B = (P_3 + P_4) - (P_3 \times P_4)$

$= (0,01493 + 0,01493) - (0,01493 \times 0,01493)$

$= (0,02986) - (0,000222)$

$= 0,02964$

$P_C = P_5$

$= 0,01493$

$P_D = P_6$

$= 0,01493$

$P_{\text{Incorrect Cutting}} = (P_A + P_B + P_C + P_D) - (P_A \times P_B \times P_C \times P_D)$

$= (0,03365 + 0,02964 + 0,01493 + 0,01493) - (0,03365 \times 0,02964 \times 0,02238 \times 0,01493)$

$= (0,093143 - 0,000000022227)$

$= 0,09314 = 9,314\%$

After evaluation :

$P_{k1} = P_1 = 0,01493$ $P_{k4} = P_4 = 0,01493$

$P_{k2} = P_2 = 0,01900$ $P_{k5} = P_5 = 0,01493$

$P_{k3} = P_3 = 0,01493$ $P_{k6} = P_6 = 0,01493$

$P_T = P_{K1} + P_{K2} + P_{K3} + P_{K4} + P_{K5} + P_{K6}$

$= 0,01493 + 0,01900 + 0,01493 + 0,01493 + 0,01493 + 0,01493$

$= 0,09365 = 9,365\%$

Based on the calculations performed, the probability of the loose seams defect before evaluation is 9,314% and after evaluation is 9,365%.

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3. Asymmetrical Cut

The following figure presents the defect structure for asymmetrical cut defects :

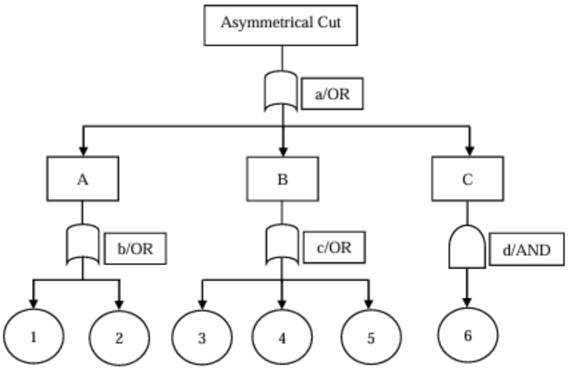

Figure 14. Fault Tree Analysis of Asymmetrical Cut Defect

Description :
A: Improper material positioning
B: Suboptimal machine condition
C: Inconsistent plastic roll quality
1 : Unstable sealing temperature
2 : Misaligned pulling rollers
3 : Damage or wear of equipment components
4 : Insufficient frequency of quality monitoring during the production process
5 : Operator failure to ensure proper material positioning prior to sealing or punching stages
6 : Uneven or wavy plastic rolls

The cut set matrix derived from the fault tree diagram for the asymmetrical defect event is obtained as follows:

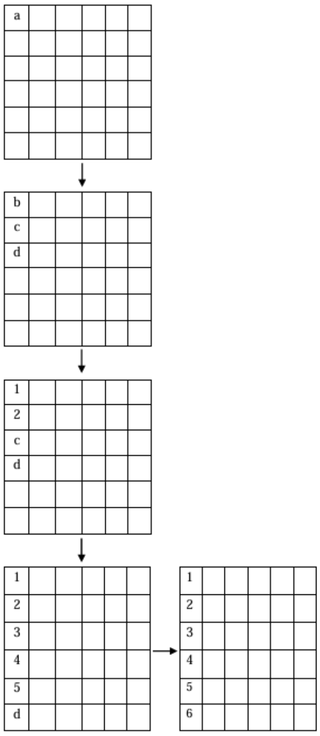

Figure 15. Cut Set Matrix and Minimal Cut Set for Asymmetrical Cut Defects

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The following figure presents the equivalent Fault Tree Analysis of the asymmetrical cut defect :

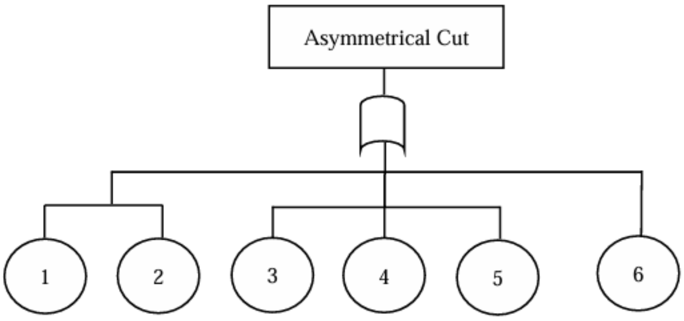

Figure 16. Equivalent Fault Tree Analysis of Asymmetrical Cut Defect

Probability calculation of Asymmetrical "Cut defects

P_1 = 0,01493 P_4 = 0,01900

P_2 = 0,01900 P_5 = 0,01493

P_3 = 0,01493 P_6 = 0,01493

$P_A = (P_1 + P_2) - (P_1 \times P_2)$

$= (0{,}01493 + 0{,}01900) - (0{,}01493 \times 0{,}01900)$

$= (0{,}03393) - (0{,}00028367)$

$= 0{,}03365$

$P_B = (P_3 + P_4 + P_5) - (P_3 \times P_4 \times P_5)$

$= (0{,}01493 + 0{,}01900 + 0{,}01493) - (0{,}01493 \times 0{,}01900 \times 0{,}01493)$

$= (0{,}04886) - (0{,}0000004235)$

$= 0{,}04886$

$P_C = P_6$

$= 0{,}01493$

$P_{\text{Asymmetrical Cut}} = (P_A + P_B + P_C) - (P_A \times P_B \times P_C)$

$= (0{,}03365 + 0{,}04886 + 0{,}01493) - (0{,}03365 \times 0{,}04886 \times 0{,}01493)$

$= (0{,}097432) - 0{,}000002454)$

$= 0{,}9741 = 9{,}741\%$

After evaluation :

$P_{k1} = P_1$ = 0,01493 $P_{k4} = P_4$ = 0,01900

$P_{k2} = P_2$ = 0,01900 $P_{k5} = P_5$ = 0,01493

$P_{k3} = P_3$ = 0,01493 $P_{k6} = P_6$ = 0,01493

$P_T = P_{K1} + P_{K2} + P_{K3} + P_{K4} + P_{K5} + P_{K6}$

$= 0{,}01493 + 0{,}01900 + 0{,}01493 + 0{,}01900 + 0{,}01493 + 0{,}01493$

$= 0{,}09772 = 9{,}772\%$

Based on the calculations performed, the probability of the loose seams defect before evaluation is 9,741% and after evaluation is 9,772%.

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4. No Handle Hole

The following figure presents the defect structure for no handle hole defects :

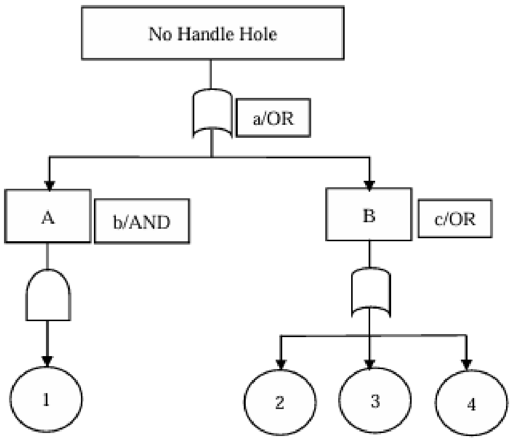

Figure 17. Fault Tree Analysis of No Handle Hole Defect

Description :
A: Improper material positioning
B: Residual material contamination and decreased machine component performance
1 : Residual material from previous processes adhering to the mold
2 : Punching mold jamming
3 : Damage or wear of equipment
4 : Operator failure to ensure proper material positioning prior to sealing or punching stages

The cut set matrix derived from the fault tree diagram for the no handle hole defect event is obtained as follows:

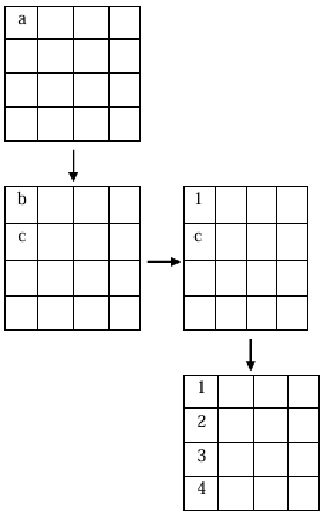

Figure 18. Cut Set Matrix and Minimal Cut Set for No Handle Hole Defects

The following figure presents the equivalent Fault Tree Analysis of the no handle hole defect :

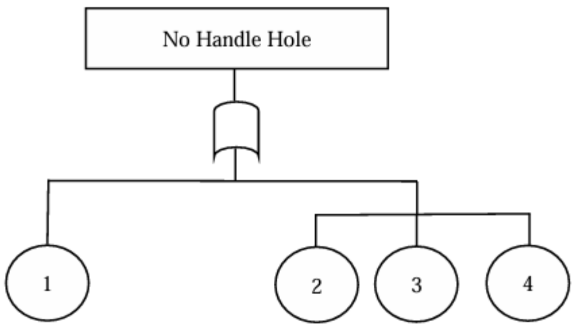

Figure 19. Equivalent Fault Tree Analysis of No Handle Hole Defect

Probability calculation of No Handle Hole defects

$P_1 = 0{,}01493$ $\quad P_3 = 0{,}02234$

$P_2 = 0{,}01493$ $\quad P_4 = 0{,}01493$

$$P_A = P_1 = 0{,}01493$$

$$P_B = (P_2 + P_3 + P_4) - (P_2 \times P_3 \times P_4)$$
$$= (0{,}01493 + 0{,}02234 + 0{,}01493) - (0{,}01493 \times 0{,}02234 \times 0{,}01493)$$
$$= (0{,}0522) - (0{,}00000049797)$$
$$= 0{,}0522$$

$$P_{\text{No Handle Hole}} = (P_A + P_B) - (P_A \times P_B)$$
$$= (0{,}01493 + 0{,}0522) - (0{,}01493 \times 0{,}0522)$$
$$= (0{,}067125) - (0{,}0007792)$$
$$= 0{,}06635 = 6{,}635\%$$

After evaluation :

$P_{k1} = P_1 = 0{,}01493$ $\quad P_{k3} = P_3 = 0{,}02234$

$P_{k2} = P_2 = 0{,}01493$ $\quad P_{k4} = P_4 = 0{,}01493$

$$P_T = P_{K1} + P_{K2} + P_{K3} + P_{K4}$$
$$= 0{,}01493 + 0{,}01493 + 0{,}02234 + 0{,}01493$$
$$= 0{,}06713 = 6{,}713\%$$

Based on the calculations performed, the probability of the loose seams defect before evaluation is 6,635% and after evaluation is 6,713%.

F. Failure Mode and Effects Analysis (FMEA)

After the failure-causing components are identified through Fault Tree Analysis (FTA), the next step is to establish improvement priorities and formulate recommended actions to enhance the quality of 15×30 HDPE plastic bags. This analytical stage is carried out using Failure Mode and Effect Analysis (FMEA), which allows each failure mode to be systematically evaluated based on severity, occurrence probability, and detectability. The primary input for FMEA comes from the list of failure components mapped through FTA, making this method a structured continuation of the evaluation process. Meanwhile, supporting data particularly concerning actual process conditions and the effectiveness of quality controls are collected through in-depth interviews with the Quality Control (QC) team to ensure that the risk assessment is based on valid empirical information. The following presents the Risk Priority Number (RPN) :”

Table 4. RPN (Risk Priority Number)

Potential Failure Modes	Potential Effect of Failure	Potential Cause	RPN	Rekomendation
Folded	Folded Defects can cause the surface of the plastic bag to appear uneven and untidy, damaging the product’s visual appearance and lowering perceived quality. Folds that persist through to the final process may also weaken areas of the plastic, making them prone to tearing, which can ultimately lead to customer complaints.	1. Lack of operator attentiveness in monitoring film movement during passage through the pulling rollers	280	1. Implement a daily monitoring checklist to ensure operators perform visual inspections during each shift and that QC conducts periodic verification to confirm inspections are carried out according to standards.
		2. Operator fatique resulting in delayed responses to machine irregularities		2. Establish operator rotation schedules to prevent prolonged assignment in areas requiring high concentration.

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Potential Failure Modes	Potential Effect of Failure	Potential Cause	RPN	Rekomendation
		3. Imbalance in the pulling system or sheet positioning control		3. Perform preventive checks and adjustments on the puller system and sheet alignment according to established standards.
		4. Winding motor not synchronized with the extrusion speed		4. Conduct weekly calibration of the winder and extruder motor synchronization by technicians, using the machine panel speed indicators as standard references rather than relying solely on the operator's visual judgment
Incorrect Cutting	Incorrect Cutting Defects result in bags that do not meet the standard shape. These errors can include slanted cuts, inconsistent dimensions, or areas that are over- or under-cut. Such defects reduce the product's functionality and fit, making the bags difficult to use optimally and potentially causing customer complaints due to unmet quality expectations.	1. Lack of operator attentiveness in adjusting the position of plastic sheets on the punching machine	210	1. Require a double-check before the machine begins operation
		2. Insufficient frequency of quality monitoring during the production		2. Establish a regular QC inspection schedule and include quality checksheets as proof of inspection.
		3. Imbalance in the pulling system or sheet positioning control		3. Perform preventive checks and adjustments on the puller system and sheet alignment according to established standards
		4. Damage or wear on equipment		4. MeInspect tool conditions (e.g., blades) at each shift change, and set a lifespan limit for worn components to replace them before failure.
		5. Punching machine maintenance schedule not routinely integrated		5. Create a scheduled maintenance plan for the punching machine, which must be executed by technicians.
		6. Inadequate lighting conditions		6. Replace lights according to schedule and add additional lighting in critical areas, such as the punching table and inspection zones
Asymmetrical Cut	Asymmetrical Defects create bags with disproportionate shapes, disrupting aesthetics and making the product appear less professional. Misaligned cuts can also affect ease of use and diminish the perceived	1. Operator failure to ensure proper material positioning prior to sealing or punching stages	180	1. Correct material positioning according to guidelines and create a standard operational checklist for position verification.

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Potential Failure Modes	Potential Effect of Failure	Potential Cause	RPN	Rekomendation
	quality of the product in the eyes of consumers.	2. Insufficient frequency of quality monitoring during the production process		2. Establish a regular QC inspection schedule and include quality checksheets as proof of inspection.
		3. Unstable sealing temperature		3. Perform regular machine calibration, and operators must follow standard checking procedures consistently.
		4. Misaligned pulling rollers		4. Adjust roller positions preventively before production starts, and record calibration results to ensure consistency.
		5. Damage or wear of equipment components		5. Inspect tool conditions (blades) at each shift change and replace components before they fail, based on their usage limit.
		6. Uneven or wavy plastic rolls		6. Flatten rolls before production and check roll tension before use
No Handle Hole	No Handle Hole Defects cause the plastic bag to lose its primary function as a carry bag. The product becomes impractical and unusable for consumers, classifying it as a failed product unfit for sale, which negatively impacts customer trust.	1. Operator failure to ensure proper material positioning prior to sealing or punching stages	175	1. Correct material positioning according to guidelines and create a standard operational checklist for position verification.
		2. Punching mold jamming		2. Clean molds before and after production and conduct preventive visual inspections.
		3. Damage or wear of equipment		3. Inspect tool conditions (blades) at each shift change, and replace worn components before failure.
		4. Residual material from previous processes adhering to the mold		4. Clean all mold surfaces from leftover plastic or debris before starting each production batch, and perform preventive visual inspections

G. Discussion

The findings of this study are consistent with previous research that identifies human factors and machine conditions as the dominant contributors to defects in plastic manufacturing processes. Similar results were reported by [Rukmana et al, 2024], who found that improper machine settings and operator errors were the primary causes of cutting and sealing defects. In this study, Fault Tree Analysis (FTA) revealed that operator control, machine performance, and material handling issues were the main root causes of folded, incorrect cutting, asymmetrical, and missing handle hole defects in 15×30 HDPE plastic bags. The defect probability analysis showed relatively small differences between pre- and post-evaluation conditions, indicating that the existing production system operates at a stable level.

Based on the processed data and minimal defect structure, the root causes and probabilities of key defects in 15×30 HDPE plastic bags were analyzed using Fault Tree Analysis. Folded defects result from suboptimal operator control and mechanical system issues, with pre- and post-evaluation probabilities of 7,079% and 7,274%. Incorrect cutting defects are caused by operator inaccuracies, machine condition, inconsistent maintenance, and inadequate workspace, with probabilities of 9,314% and 9,365%. Asymmetrical defects stem from improper material placement, machine performance, and uneven plastic rolls, with probabilities of 9,741% and 9,772%. Missing handle hole defects arise from material misplacement and tool contamination or wear, with

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probabilities of 6,635% and 6,713%. Overall, the analysis shows that evaluation did not significantly change the defect probabilities, indicating that the system and preventive measures are performing optimally.

Based on the FMEA analysis, folded defects have the highest RPN of 240 and are caused by suboptimal operator control and mechanical system issues, such as inattention to film movement, operator fatigue, puller imbalance, and unsynchronized winder motors. Recommended improvements include daily monitoring checklists, operator rotation, preventive system adjustments, and weekly motor synchronization calibration. Incorrect cutting defects (RPN 210) result from inaccurate operator settings, suboptimal machine conditions, inconsistent maintenance, and poor lighting, with corrective actions including double checks before operation, regular QC inspections with checksheets, preventive system adjustments, tool inspections, scheduled machine maintenance, and improved lighting. Asymmetrical defects (RPN 180) are due to improper material placement, machine inconsistencies, and uneven plastic rolls, with recommendations including material position correction, regular QC inspections, machine calibration, preventive roller adjustments, tool inspections, and roll flattening. Missing handle hole defects (RPN 175) arise from improper material placement, punching mold jams, tool wear, and leftover material, with improvements including material position correction, mold cleaning before and after production, preventive visual inspections, and tool condition checks to replace worn components before failure.

Conclusion

Based on the analysis of the 15×30 High Density Polyethylene (HDPE) plastic bag production process at PT XYZ, four dominant defect types were identified, namely asymmetrical defects, incorrect cutting, folded defects, and missing handle holes. Among these, asymmetrical and incorrect cutting defects showed the highest defect probabilities. The integration of Fault Tree Analysis (FTA) and Failure Mode and Effect Analysis (FMEA) enabled systematic identification of root causes and effective prioritization of improvement actions based on Risk Priority Number (RPN) values.

Improvement recommendations were formulated according to RPN priorities and focus on strengthening operator performance, improving adherence to standard operating procedures (SOPs), and enhancing machine reliability through preventive maintenance and routine calibration. The proposed actions are practical and applicable, providing direct guidance for improving product quality and reducing defect rates at PT XYZ. Continuous and periodic quality monitoring is essential to ensure the sustainability of these improvements. Future studies may consider applying advanced approaches, such as Fuzzy FMEA, to address uncertainty and further enhance decision-making in quality improvement initiatives.

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References

1. R. Ramdani and M. Fadilah, “Analisis Pengendalian Kualitas PT DMI Untuk Mengurangi Tingkat Kerusakan Pada Produk Servo Motor Dengan Menggunakan Metode Six Sigma,” Journal of System and Software Research, vol. 3, no. 2, pp. 13–25, 2025, doi: 10.61722/jssr.v3i2.3792.
2. N. Z. Laily, R. Septiari, and E. Adriantantri, “Identifikasi Defect Pada Proses Produksi Benang Dalam Upaya Pengendalian Kualitas Di PT Leo Textil,” Jurnal Senopati, vol. 6, no. 2, pp. 151–158, 2025, doi: 10.31284/j.senopati.2025.v6i2.7387.
3. S. A. Rais and A. S. Cahyana, “Defect Analysis and Solution Through Revolutionizing Recycled Paper Production,” Indonesian Journal of Innovation Studies, vol. 25, no. 3, pp. 1–11, 2024, doi: 10.21070/ijins.v25i3.1163.
4. M. F. Baad, D. Andesta, and Hidayat, “Analysis of Quality Improvement of Wood Powder Raw Materials at CV NKM Using FMEA and FTA Methods,” G-Tech: Journal of Technology, vol. 8, no. 1, pp. 186–195, 2024. [Online]. Available: https://ejournal.uniramalang.ac.id/index.php/g-tech/article/view/1823/1229
5. A. N. Rukmana et al., “Enhancing Reliability in Garment Manufacturing Through FMEA and FTA,” Applied Logistics, vol. 11, no. 4, pp. 579–587, 2024, doi: 10.22306/al.v11i4.548.
6. Z. Ramadhani and Y. P. Negoro, “Penerapan Failure Mode and Effect Analysis (FMEA) Dan Fault Tree Analysis (FTA) Untuk Mengidentifikasi Kecacatan Palet Kayu (Studi Kasus: CV Mandiri Jaya),” Jurnal Teknik Manajemen Industri dan Teknologi, vol. 4, no. 3, pp. 815–824, 2025, doi: 10.55826/jtmit.v4i3.1039.
7. A. Wicaksono and F. Yuamita, “Pengendalian Kualitas Produksi Sarden Menggunakan Metode Failure Mode and Effect Analysis (FMEA) Dan Fault Tree Analysis (FTA) Untuk Meminimalkan Cacat Kaleng Di PT XYZ,” Jurnal Teknologi Manajemen Industri, vol. 1, no. 3, pp. 145–154, 2022, doi: 10.55826/tmit.v1i3.44.
8. R. Fitriana and I. P. Sari, “Peningkatan Kualitas Proses Produksi Tahu Menggunakan Metode FMEA Dan FTA (Studi Kasus: Pabrik Tahu DN),” Jurnal Teknologi Industri Pertanian, vol. 33, no. 3, pp. 277–289, 2023, doi: 10.24961/j.tek.ind.pert.2023.33.3.277.
9. A. Dharma and M. Nuruddin, “Analyzing Product Defects in the Production Process of Tempeh Using the FTA and FMEA Methods at CV Aderina,” Motivection: Journal of Mechanical, Industrial and Manufacturing Engineering, vol. 5, no. 3, pp. 571–582, 2023, doi: 10.46574/motivection.v5i3.269.
10. P. A. V. Prasmoro and M. Widyantoro, “Analisis Penerapan Program Keselamatan Kerja Pada Lantai Produksi Dengan Metode Fault Tree Analysis (FTA) Di PT XYZ,” Jurnal Riset Logistik Indonesia, vol. 21, no. 2, pp. 75–82, 2021, doi: 10.37412/jrl.v21i2.119.
11. W. Ridwan, R. Wulandari, and E. Nurhayati, “Analisis Pengendalian Kualitas Bibit Sawit Dengan Menggunakan Metode Fault Tree Analysis (FTA) Dan Failure Mode and Effect Analysis (FMEA),” Reslaj: Religion Education Social Laa Roiba Journal, vol. 5, no. 6, pp. 3730–3738, 2023, doi: 10.47476/reslaj.v5i6.2741.
12. M. J. Firmansyah and M. Nuruddin, “Analisis Pengendalian Kualitas Produksi Pada PT XYZ Menggunakan Metode Seven Tools Dan FMEA,” SITEKIN: Jurnal Sains, Teknologi dan Industri, vol. 20, no. 1, pp. 231–238, 2022, doi:

10.24014/sitekin.v20i1.19457.
13. H. Prisilia and D. A. Purnomo, “Manajemen Risiko K3 Dengan Metode Failure Mode and Effect Analysis (FMEA) Dan Fault Tree Analysis (FTA) Untuk Mengidentifikasi Potensi Dan Penyebab Kecelakaan Kerja (Studi Kasus: Tahap II Pembangunan Gedung Laboratorium DLH Banyuwangi),” Tekmapro: Journal of Industrial Engineering and Management, vol. 17, no. 2, pp. 1–12, 2022, doi: 10.33005/tekmapro.v17i2.299.
14. A. F. Hafiduddin and Sumiati, “Analysis of Defects in White Crystal Sugar Products at XYZ Sugar Factory Using Fault Tree Analysis (FTA) and Failure Mode and Effect Analysis (FMEA),” Applied Science and Industrial Engineering Conference Proceedings, vol. 6, no. 1, pp. 1–7, 2024, doi: 10.35877/454RI.asci2694.
15. W. Kurniawan, D. K. Sari, and F. Sabrina, “Perbaikan Kualitas Menggunakan Metode Failure Mode and Effect Analysis Dan Fault Tree Analysis Pada Produk Punch Extruding Red,” E-Kombis: Jurnal Ekonomi dan Bisnis, vol. 10, no. 1, pp. 152–166, 2022, doi: 10.37676/ekombis.v10i1.

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