

Article

Risk Control Analysis Embroidery Process Using Failure Mode and Effect Analysis and Fault Tree Analysis

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Abstract: The embroidery industry is highly competitive, requiring companies to produce high-quality products. However, the embroidery process still exhibits a relatively high level of risk. From July to December, total production reached 22,000 units, with 1,200 units being defective, or approximately 5.45%. This study aimed to determine the highest risk level in the embroidery process using the Failure Mode and Effect Analysis (FMEA) method, analyze the root causes using Fault Tree Analysis (FTA), and provide recommendations for improvement. The results revealed seven types of risks in the embroidery process. Based on the FMEA analysis, the first highest risk was the embroidery machine suddenly stopping (RPN 432), the second was thread breaking during operation (RPN 384), and the third was tangled or clumped embroidery during the installation process (RPN 252). The FTA analysis indicated that the main causes stemmed from machine factors and production process settings. Recommendations for improvement include re-inspecting the machine to prevent failures and re-inspecting before production

Keywords: Risk Analysis, Failure Mode and Effect Analysis (FMEA), Fault Tree Analysis (FTA), Embroidery Production Process, Quality Control

Citation: Marodiyah, I., Saputra R. H.. Risk Control Analysis Embroidery Process Using Failure Mode and Effect Analysis and Fault Tree Analysis. International Journal on Orange Technologies (IJOT) 2026, 8(3), 24-36.

Received: 30th Apr 2026Revised: 20th May 2026Accepted: 15th Jun 2026Published: 07th Jul 2026

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1. Introduction

The development of the embroidery industry in Sidoarjo Regency shows significant growth along with increasingly modern technological advances. This condition makes competition between embroidery industry players increasingly fierce. As a result of increasingly fierce competition, companies are required to have a competitive advantage in order to survive and continue to develop their business. Therefore, every company must be able to produce high-quality products [1]. The production process in this industry involves several important stages, such as design preparation, material determination, machine settings, and the embroidery process itself. Risk contains uncertainty and has the potential to cause obstacles, one of which is operational problems [2]. By implementing efficient quality risk management, companies are able to reduce risk levels and build systems that can identify potential risks that arise along with strategies for handling them [3].

The embroidery production process at a company specializing in embroidered school logos continues to experience a relatively high and poorly controlled product defect rate. Based on production data from July to December, a total of 22,000 units were produced, with 1,200 identified as defective, resulting in an average defect rate of 5.45%. Common defects observed include thread breaks, skipped stitches, irregular or asymmetrical embroidery patterns, fabric tears due to broken needles, wrinkled or uneven embroidery,

typographical or design errors, and excess thread. Therefore, a risk identification process is carried out to identify various risks that may occur during the process [4].

To address these issues, a risk management method is required. One approach that can be applied is Failure Mode and Effect Analysis (FMEA). FMEA is a methodical approach to risk management that can be used to assess and record the reasons behind process failures [5]. FMEA is a method used to define and identify defects in production processes [6]. This method helps prioritize risk levels so that the most critical failures can be addressed immediately [7]. Failure Mode and Effect Analysis (FMEA) is used to identify potential risks that may occur in a process and to develop appropriate actions to minimize or prevent them. [8].

In addition, FMEA is integrated with other methods, one of which is Fault Tree Analysis (FTA). FTA is a systematic analysis technique that applies a top-down approach, starting from a defined main event and tracing it back to determine its root causes [9]. This method helps in identifying and mitigating potential failures within systems and processes before the product or service reaches the customer [10]. The primary objective of FTA is to identify and analyze the underlying causes of each type of failure or problem [11].

Suseno's 2022 study, "Quality Control of Leather Bag Product Defects Using FMEA and FTA Methods at PT Mandiri Jogja Internasional," concluded that FMEA and FTA methods can be used to analyze the causes of product defects, prioritize problems, and identify the root causes of defects that occur during the production process [12]. Ahmad Fasih Hasibu Dzikri's (2024) study, "Quality Control Analysis of Songkok Products Using FMEA and FTA Methods at CV. ABC," showed that through FMEA, the highest failure factor was a broken sewing machine needle with an RPN value of 448. Meanwhile, FTA analysis revealed that failures were caused by human factors, machine factors, and poor raw material quality [13].

Based on previous research, the FMEA and FTA methods are capable of measuring and identifying risks in the embroidery production process. Therefore, this study aims to determine the highest RPN value in the embroidery process using the FMEA method, identify the root causes of the highest embroidery process problems using FTA, and provide recommendations for improvements to the embroidery process. Therefore, this study is expected to provide an overview of the highest risks that can be followed up.

2. Materials and Methods

The research was conducted at an embroidery industry in Sidoarjo Regency, focusing on the automated embroidery process. Data collection took place from September 2025 to January 2026.

This research was conducted through several structured stages to ensure the entire research process was carried out effectively and in accordance with the stated objectives. Each stage was systematically structured to facilitate research implementation and analysis. The stages in this research are explained as follows:

1. Research Flow:

In this research, the methods that will be used are the Failure Mode and Effect Analysis (FMEA) and Fault Tree Analysis (FTA) methods with the following research flow:

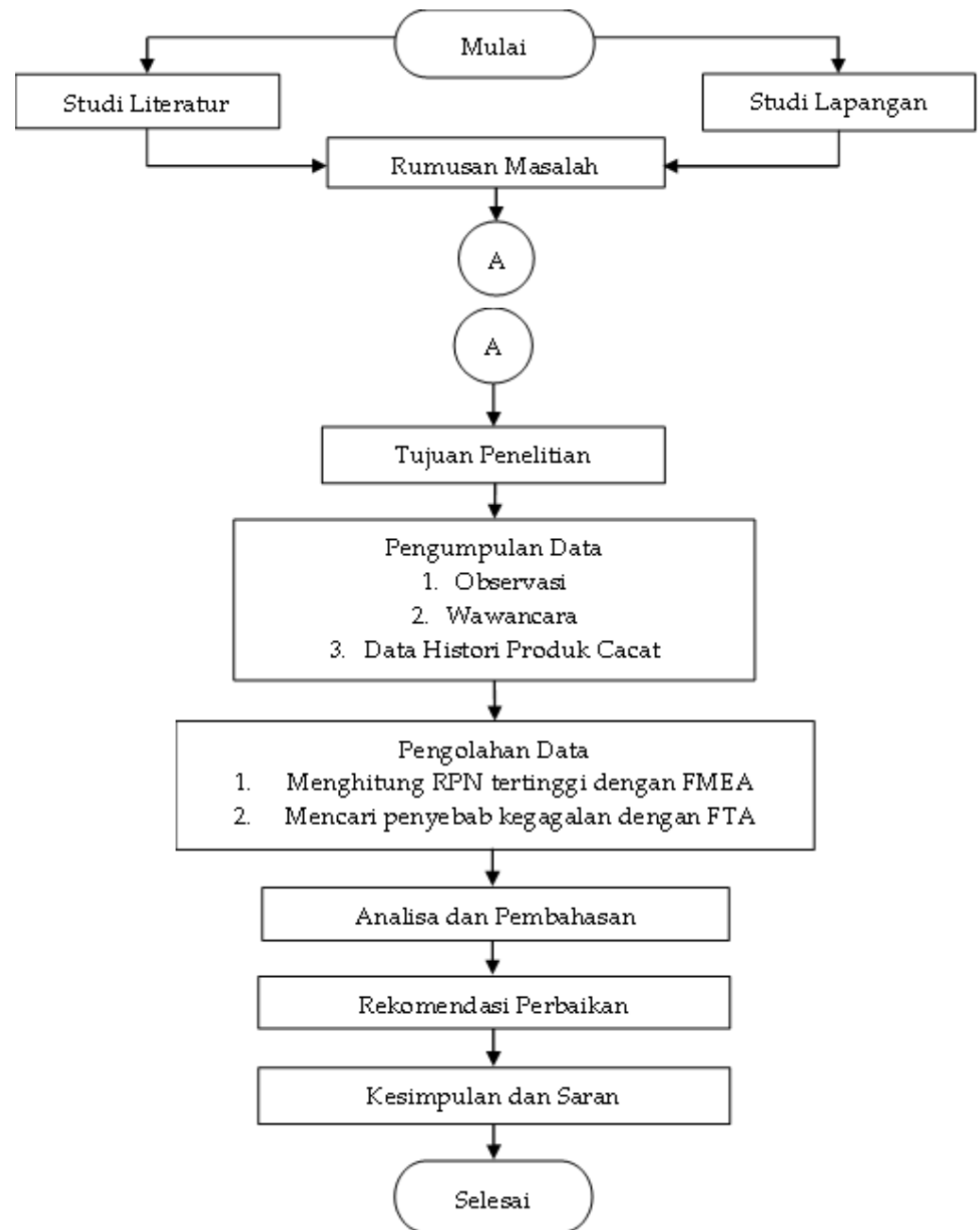


Figure 1. Research Flow.

2. Literature Review

The literature review was conducted by examining textbooks, scientific journals, research articles, and other references relevant to the topic of risk management in the embroidery process. This study aimed to understand the concept of risk, operational risk management, embroidery process characteristics, and the Failure Mode and Effects Analysis (FMEA) and Fault Tree Analysis (FTA) methods as the theoretical basis for the research.

3. Field Study

The field study was conducted by directly observing the embroidery process at the company to identify process stages, actual operating conditions, and potential risks that arise during production. The data obtained from the field study was used as the basis for developing the Failure Mode and Effects Analysis (FMEA) and Fault Tree Analysis (FTA).

4. Problem Formulation

Based on the results of the problem identification and literature review, a systematic problem formulation was conducted. The problem formulation was formulated to determine the research focus, namely: how to determine the risk level of the embroidery process and the factors that contribute to failure.

5. Research Objectives

Based on the problem formulation, this study aims to determine the highest RPN value in the embroidery process using the FMEA method, identify the root causes of the highest embroidery process problems using FTA, and provide recommendations for improvements to the embroidery process.

6. Data Collection

In this study, two types of data were collected: primary and secondary data. Primary data was obtained directly from the field through observations of the embroidery process and interviews with business owners to determine the types of failures, their frequency, and the causal factors. Secondary data was obtained from company documents such as production records, historical product defect data, and supporting literature in the form of journals and scientific references related to the FMEA and FTA methods.

7. Data Processing

The collected data was then processed using the predetermined methods, namely FMEA and FTA. Data processing included:

A. Failure Mode and Effect Analysis

FMEA is an analytical tool used systematically by academics and industry to identify and comprehensively evaluate risks. The FMEA method considers three primary risks: Severity (S), Occurrence (O), and Detection (D), with each factor assessed on a 10-point scale to determine the level of risk associated with each failure mode [14]. The ratings for Severity, Occurrence, and Detection are used to determine the RPN value in the FMEA table, which can be measured on a scale of 1 to 10, with 1 indicating the lowest impact and 10 indicating the highest impact [15]. The formula used to calculate the Risk Priority Number (RPN) is as follows:

$$RPN = S \times O \times D [16]$$

Description:

S = Severity

O = Occurrence

D = Detection

RPN is determined by multiplying three levels of assessment calculations: impact, reason, and identification at each stage, also known as the multiplication of severity (S), occurrence (O), and detection (D). Severity is used to evaluate the extent of the impact if a failure occurs. The severity assessment criteria can be seen in the following table.

Table 1. Severity Value (S).

Description	Severity	Rating
System failure causes a major impact and high risk	Risky	10
System error has the potential to cause a very serious impact	Serious	9
The system stops and cannot operate	Very High	8
The system runs but does not function optimally	High	7
The system operates safely, but performance decreases	Moderate	6
A gradual decline in system performance occurs	Low	5
Impact on system performance is very small	Very Low	4

Slightly affects system performance	Minor Impact	3
Almost no effect on system performance	Very Minor Impact	2
No effect on the product	No Impact	1

Source: [17].

Furthermore, occurrence (O) is used to assess the likelihood of a cause that could potentially lead to failure in a process. The occurrence assessment indicates how often the failure could occur. The occurrence (O) value can be seen in the following table.

Table 2. Occurrence Value (O).

Description	Occurrence	Rating
Failure is almost certain to occur	Almost Certain	10
A very high failure rate occurs frequently	Very High	9
High probability of failure	High	8
Failure is quite likely to occur frequently	Moderately High	7
Failure may occur at a moderate level	Moderate	6
Failure may occasionally occur under certain conditions	Low	5
Low probability of failure or rarely occurs	Small	4
Very low probability of failure	Very Small	3
Failure is very unlikely	Very Rare	2
Failure is almost impossible to occur	Almost Never	1

Source: [18]

Detection is then used to prevent or address potential problems and reduce the likelihood of failure. The detection values are shown in the table below.

Table 3. Detection Value (D).

Description	Detection	Rating
The inspection process is unable to identify the cause or type of failure	Almost Impossible	10
The inspection process very rarely identifies causes and failure modes	Rare	9
Inspection has a very low chance of detecting causes and failure modes	Very Low	8
Inspection has a limited ability to identify causes and failure modes	Low	7
Inspection has low capability to detect causes and failure modes	Moderately Low	6
Inspection has a moderate chance of identifying causes and failure modes	Moderate	5
Inspection has a fairly high chance of detecting causes and failure modes	Moderately High	4
Inspection has a high probability of detecting causes and failure modes	High	3

Inspection has a very high probability of detecting causes and failure modes	Very High	2
Inspection almost always successfully identifies causes and failure modes	Almost Certain	1

Source: [17]

Then, risk categories are determined to determine the highest priority obtained from the FMEA calculations. The table below shows the risk category determination.

Table 4. Risk Category Determination.

Risk Priority Number (RPN)	Category
193 – 1000	High (Requires Risk Control Action)
65 – 192	Medium (Reduce Risk to the Lowest Possible Level)
0 – 64	Low (Acceptable Risk)

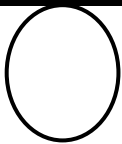
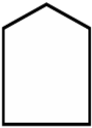
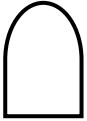
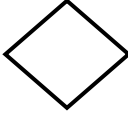
Source: [19]

B. Fault Tree Analysis

Fault Tree Analysis (FTA) is a widely used failure analysis technique to identify potential pathways that can lead to failure in a system or component. This technique has been applied in various sectors to understand failure mechanisms and determine appropriate corrective actions [20]. Fault trees provide a framework for qualitative and quantitative evaluation of top events. The steps in implementing FTA include defining top events and system structure, exploring each branch of the tree, solving the fault tree for combinations of events, conducting qualitative analysis, and using the results as a basis for decision-making [21].

The symbols and their meanings are presented in the following table.

Table 5. FTA Symbols.

Symbol	Meaning	Simbol	Arti
	Basic Event Basic error initiation that does not require further development.		External Event An event that is expected to occur
	Conditioning Events specify conditions that can be applied to various logic gates.		AND Gate Manual error due to all input problems that occur
	Undevelopment Event An event that cannot be developed further because information is not available.		OR Gate Error occurs due to one of the input problems occurring

Source: [10]

The steps in implementing the FTA (Fault Tree Analysis) method are as follows [22]:

1. Identifying Top-Level Events, identifying the types of damage that have occurred to analyze system errors, knowledge about the system is obtained by searching for all system information or its scope.

2. Creating a Fault Tree Diagram, creating a fault tree to understand how top-level events can arise in the system.
3. Analyzing the Fault Tree, analyzing the fault tree aims to obtain transparent information about the system and necessary improvements.

The following figure illustrates an example of a Fault Tree Analysis (FTA) analysis of risks in a work process.

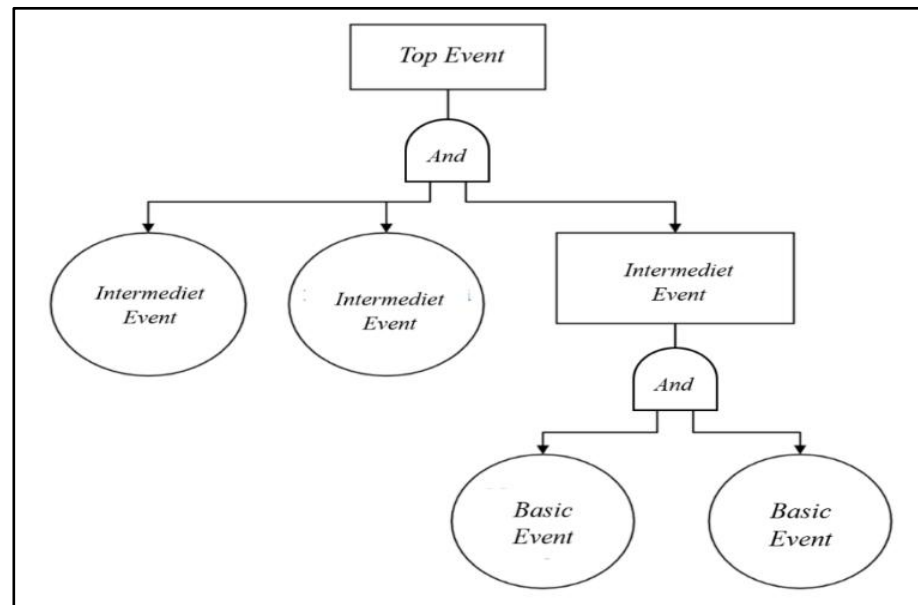


Figure 2. Example of Fault Tree Analysis.

Source: [22]

Description:

Top Event : An undesirable event

Intermediate Event : An event between the outcome and the cause

Basic Event : The most basic cause

3. Results

A. Data Collection

The research was conducted through an analysis of the company's historical data over the past six months, supported by direct interviews with the owner and production team to strengthen the identification of risks that occur during the embroidery process.

1. Historical Data

Historical data was obtained from production records and documented defect reports at each stage of the process. The table of historical product defect data is shown below.

Table 6. Historical Product Defect Data.

No	Month	Production Amount	Number of Defects	Percentage of Defects
1	Juli	4500	300	6,67%
2	Agustus	4000	150	3,75%
3	September	4000	200	5,00%
4	Oktober	3500	250	7,14%
5	November	3500	100	2,86%
6	Desember	2500	200	8,00%
Total		22000	1200	5,45%

Based on Table 6, during the six months from July to December, total production was recorded at 22,000 units, with a total of 1,200 defective units. On average, the defect rate during these six months was approximately 5.45%.

2. Risk Identification

Based on the data analysis and interviews, seven main types of risks emerged during the embroidery process. These risks were then classified according to the stages of the production process, as shown in the following table:

Table 7. Risk Identification.

No	Failure Mode	Potential Failure Effect
1	Product design error (unsuitable/asymmetrical design)	Product failure due to embroidery results not matching specifications or customer requirements
2	Skipped stitches during sewing process	Embroidery results become uneven and loose, reducing the visual quality of the product
3	Thread breakage during machine operation	Machine temporarily stops (downtime) for repair or thread reconnection
4	Needle breakage causing fabric tearing	Causes damage to the fabric and the machine stops operating
5	Wrinkled or overlapping embroidery during hooping process	Product failure due to uneven and imprecise embroidery, not meeting quality standards
6	Excess thread residue	Causes the product to appear untidy and requires additional finishing process
7	Sudden embroidery machine stoppage	Production process stops due to power disturbances or system failure, causing delays in order completion

B. Data Processing

The RPN assessment is conducted by interviewing the owner to identify key points. Then, a questionnaire is distributed to employees who are experts in their respective fields and assigning scores for each failure mode occurring in the drum chrome process based on severity, occurrence, and detection. The RPN value is obtained by multiplying S, O, and D.

$$RPN = S \times O \times D. [9]$$

Table 8. RPN Calculation Results.

No	Risk Activity in Embroidery Process	Potential Failure Cause	Potential Failure Effect	S	O	D	RPN
1	Product design error (unsuitable/asymmetrical design)	Errors in embroidery design creation, incorrect design file, or wrong pattern input	Product failure due to embroidery results not matching specifications or customer requirements	10	6	2	120
2	Skipped stitches during sewing process	Incorrect thread tension, dull	Embroidery results are uneven and loose, reducing the	7	6	4	168

		needle, or improper thread installation	visual quality of the product Machine				
3	Thread breakage during machine operation	Poor thread tension or low-quality thread	temporarily stops (downtime) for repair or thread reconnection	8	6	8	384
4	Needle breakage causing fabric tearing	Worn needle, improper needle installation, or excessive machine speed	Causes damage to the fabric and the machine stops operating	9	3	2	54
5	Wrinkled or overlapping embroidery during hooping process	Fabric not tightly hooped, incorrect machine pressure settings, or no backing material	Product failure due to uneven and imprecise embroidery, not meeting quality standards	7	6	6	252
6	Excess thread residue	Imperfect thread trimming process or lack of operator attention during finishing	Causes the product to appear untidy and requires additional finishing process	3	6	8	144
7	Sudden embroidery machine stoppage	Power disturbances, machine component failure, or control system errors	Production process stops, causing delays in order completion	8	6	9	432

Table 9. Determination of Risk Categories.

No.	Risk Activity in Embroidery Process	S	O	D	RPN	Category
1	Product design error (unsuitable/asymmetrical design)	10	6	2	120	Medium
2	Skipped stitches during sewing process	7	6	4	168	Medium
3	Thread breakage during machine operation	8	6	8	384	High
4	Needle breakage causing fabric tearing	9	3	2	54	Low
5	Wrinkled or overlapping embroidery during hooping process	7	6	6	252	High
6	Excess thread residue	3	6	8	144	Medium
7	Sudden embroidery machine stoppage	8	6	9	432	High

Based on Table 8, the highest RPN value was obtained for the risk of the embroidery machine suddenly stopping, at 432, making it the top priority for repair. The second highest risk was thread breaking while the machine was running, with an RPN of 384, and the third highest risk was embroidery wrinkling or bunching during the beading process, with an RPN of 252.

C. Analysis and Discussion

Fault tree analysis based on the RPN calculation table and the risk category determination table revealed three potential risks with higher values than the others, requiring further analysis to identify the causal factors. These three risks are: 1) the embroidery machine suddenly stopping, 2) thread breaking while the machine was

running. 3) embroidery wrinkling or bunching during the beading process. Therefore, a fault tree diagram was created and analyzed. First, an FTA was prepared for the risk of the embroidery machine suddenly stopping, as follows:

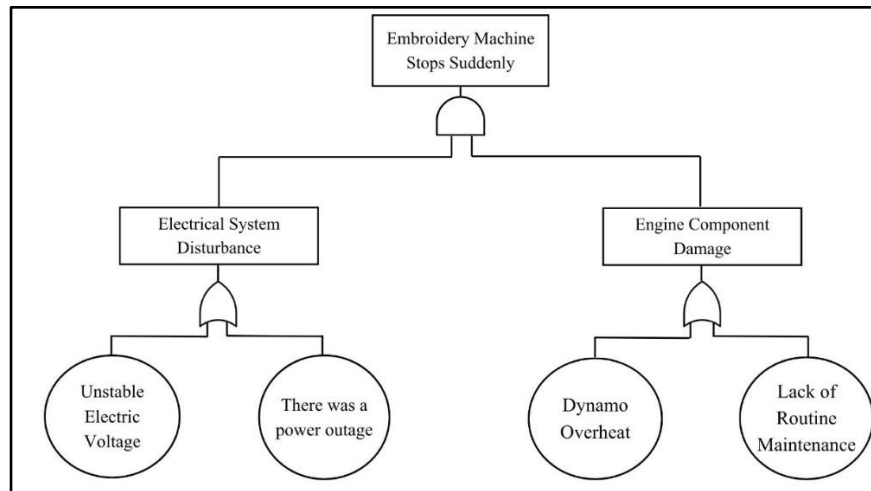


Figure 3. Fault Tree Analysis of Embroidery Machine Sudden Stoppage.

Based on Figure 3, the embroidery machine's sudden stoppage was analyzed and identified as being caused by several primary factors, including electrical system disruptions such as unstable voltage and power outages, machine component damage such as an overheated dynamo, and a lack of routine maintenance.

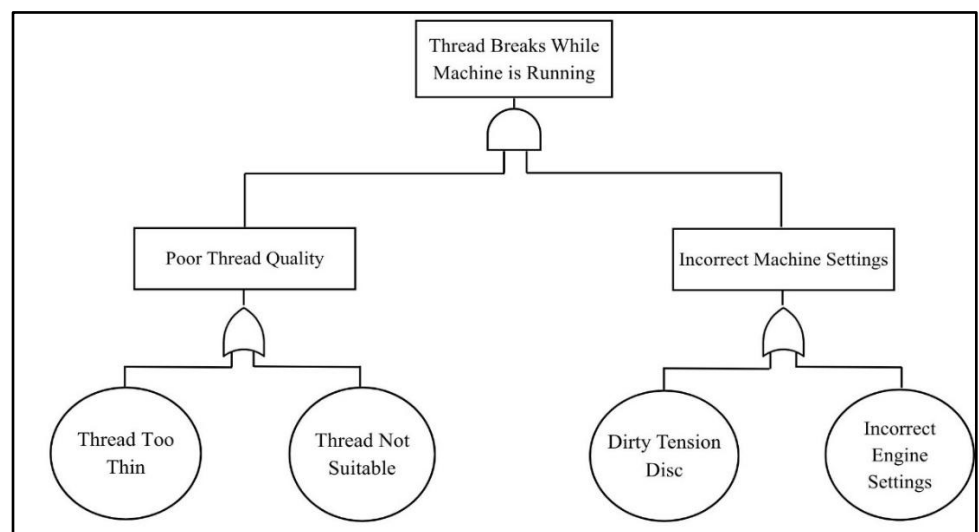


Figure 4. Fault Tree Analysis of Thread Breakage While the Machine is Running.

Based on Figure 4, the thread breakage while the machine is running is analyzed to identify several main factors, including poor thread quality caused by thread that is too thin or unsuitable, and poor thread tension caused by a dirty tension disc or incorrect machine settings.

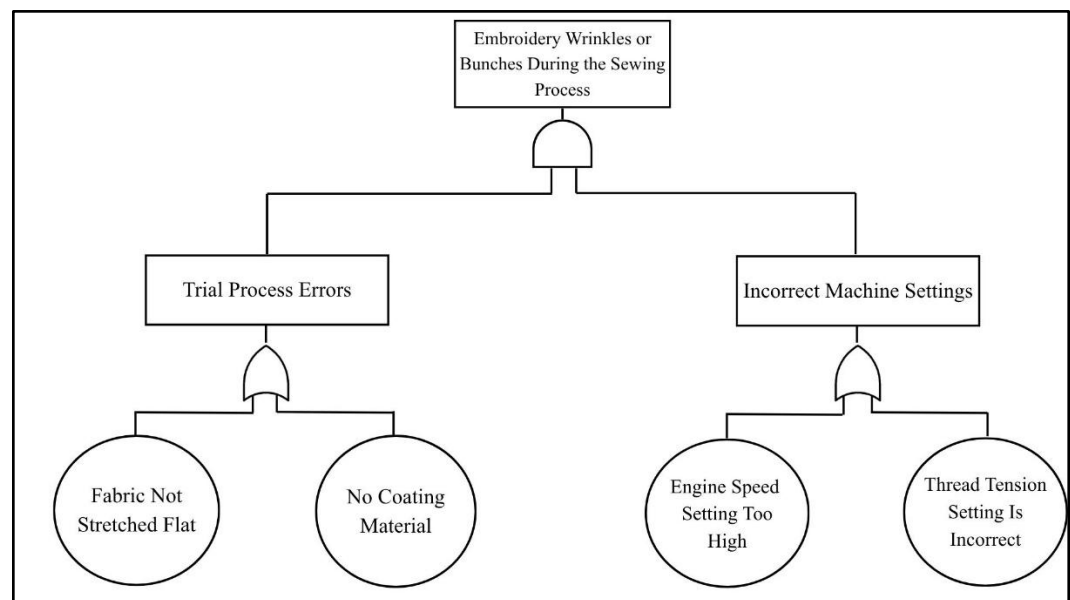


Figure 5. Fault Tree Analysis of Wrinkled or Bunched Embroidery During the Pinning Process.

Based on Figure 5, which shows wrinkled or bunched embroidery during the pinning process, the analysis concluded that this risk was caused by errors in the pinning process, such as the fabric not being pulled evenly or the absence of lining material, which causes the fabric to shift easily, and inappropriate machine settings, such as setting the machine speed too high or setting the thread tension incorrectly.

D. Recommendations for Improvement

Based on the results of the FMEA and FTA analyses, several recommendations for improvement based on the three highest RPN values are:

1. Re-inspect the machine to prevent failure.
2. Re-inspection is necessary before production [23].
3. Set an optimal and effective production schedule for the embroidery machine [24].
4. The company needs to perform regular machine maintenance to prevent damage.
5. Ensure all machines and equipment used comply with established company SOP [25].

4. Discussion

Based on the Risk Priority Number (RPN) calculation results, it is identified that there are three risks categorized as high priority, which require immediate control actions. The highest RPN value is found in the risk of sudden embroidery machine stoppage, with a score of 432. This indicates that the failure has a high level of severity, occurs relatively frequently, and has a low level of detectability. The second highest risk is thread breakage during machine operation, with an RPN value of 384, showing that this issue occurs frequently and is difficult to detect before disrupting the production process. Additionally, the risk of wrinkled or overlapping embroidery during the hooping process, with an RPN value of 252, is also categorized as high, indicating issues related to improper hooping techniques and machine setting parameters.

Risks that fall into the medium category include design errors, skipped stitches during the sewing process, and excess thread residue. Although these are not as severe as the high-level risks, they still require proper control efforts to reduce their impact on product quality. In contrast, the lowest-level risk is needle breakage leading to fabric tearing, which has the smallest RPN value and is generally considered acceptable; however, it still needs to be monitored to avoid developing into more serious problems.

Overall, the findings suggest that machine-related issues and production setting parameters are the primary contributors to risks in the embroidery process. Therefore, improvement efforts should be focused on these aspects to enhance product quality and ensure a smoother production process.

5. Conclusion

1. The analysis using the FMEA method indicates that the first risk with the highest Risk Priority Number (RPN) and categorized as high risk is the embroidery machine suddenly stopping with an RPN of 432. The second highest risk with a high risk is thread breaking while the machine is running with an RPN of 384. The third highest risk with a high risk is embroidery wrinkling or bunching during the darning process with an RPN of 252. These three risks are the top priorities that require improvement.
2. The analysis using the FTA method indicates that the main causes of these risks stem from several factors, including electrical faults and lack of machine maintenance, poor thread quality and improper thread tension settings, and errors in the darning process and inappropriate machine settings.
3. Based on the FMEA and FTA analysis results, several recommendations for improvement based on the three highest RPN values are:
 - a. Re-inspection is required before production.
 - b. Re-inspection of the machine to prevent failures.
 - c. Establishing optimal and effective embroidery machine production scheduling.
 - d. Companies need to perform regular machine maintenance to prevent damage.
 - e. Ensure all machines and equipment used comply with established company SOPs.

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