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Analysis of T-Shirt Product Quality Control to Minimize Defects Using Fault Tree Analysis (FTA) and Failure Mode and Effects Analysis (FMEA) at CV Dwiputra Ihwa

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Abstract. CV Dwiputra Ihwa is a company that operates in the garment industry, specifically producing T-shirts based on special orders or in large quantities. From June 2025 to May 2026, the percentage of defective products was 7.6% out of a total production of 18,478 units. This situation leads to more rework, waste of raw materials, and lower production efficiency. This study aims to find out which type of defect is most common, look into why these defects happen, and figure out what improvements should be done first to make the T-shirt product better. The study uses a descriptive method with a qualitative approach through a case study. Data was collected through observation, interviews, and document study, then analyzed using Pareto Diagram, Fault Tree Analysis, and Failure Mode and Effect Analysis. The Pareto chart analysis shows that stitching defects (43%) and inaccurate screen-printing defects (37%) are the two main types of defects, contributing about 80% of all defective products. The FTA analysis shows that the second type of defect is caused by a combination of human factors, methods, materials, and machines (4M), with human factors and methods being the most significant causes. The FMEA analysis results show that the Risk Priority Number (RPN) ranges from 30 to 252, with the highest risk cause being overly high production targets (RPN = 252). Based on the research results, it can be concluded that using Pareto Diagram, FTA, and FMEA is effective in identifying types of defects, analyzing root causes, and determining priorities for improvement, which helps support the enhancement of the quality of T-shirts produced by CV Dwiputra Ihwa.

Keywords: *Quality Control, Defective Products, Fault Tree Analysis, Failure Mode and Effect Analysis, Risk Priority Number.*

A. INTRODUCTION

The clothing industry is a highly competitive manufacturing sector, requiring companies to consistently produce high-quality products. Product quality is crucial for satisfying customers, maintaining their trust, and remaining competitive with other companies. In the garment industry, the quality of the t-shirts produced depends on every step of the production process, from cutting the material, sewing, screen printing, and finishing. Inconsistencies at any of these stages will result in substandard products, which can increase production costs, lead to wasted raw materials, require rework, and delays in fulfilling customer orders (Sorata Putri et al., n.d.).

CV Dwiputra Ihwa is a garment manufacturing company that produces t-shirts for both custom orders and large-scale production. Based on production data from June 2025 to May 2026, the company produced 18,478 units, of which 1,405 did not meet quality standards, resulting in a defective product rate of 7.6% of total production. This percentage indicates a relatively high defect rate. According to Hamdani et al. (2026), improved quality control efforts are necessary. Initial inspection results indicate that the most common types of defects are stitching defects, incorrect screen printing, and cutting defects. This situation increases repair times, wastes materials, and makes the production process less efficient.

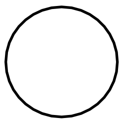
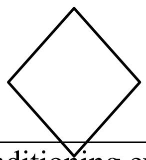
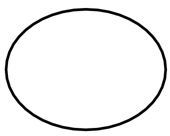
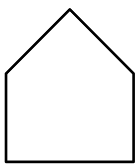
Previous studies have shown that the Fault Tree Analysis (FTA) method can systematically identify the root causes of failures down to their root cause, while Failure Mode and Impact Analysis (FMEA) is used to determine the order of risk importance based on the Risk Priority Number (RPN). Combining these two methods provides a more comprehensive approach because FTA is used to identify the relationship between the causes and impacts of defects, while (Krisnaningsih et al., 2021) uses FMEA to identify the root causes that require immediate correction. Furthermore, the 5W+1H approach can be used to develop structured and easily implemented corrective action proposals for companies.

Although many studies on quality control using the FTA and FMEA methods have been conducted in various manufacturing sectors, there are not many studies that combine the Pareto Diagram, FTA, FMEA, and 5W + 1H in the T-shirt production process at CV Dwiputra Ihwa. Therefore, this study aims to determine the most frequent types of defects, analyze the main causes of defects using the FTA method, determine the order of vulnerability of defect causes based on the RPN value using the FMEA method, and make recommendations for improvements using the 5W + 1H approach as an effort to reduce the level of defects in T-shirt products. The results of this study are expected to be used as a basis for companies to improve their quality control capabilities, reduce the number of products that do not meet standards, and increase the efficiency of the production process in a sustainable manner (Anwar et al., 2023).

B. METHOD

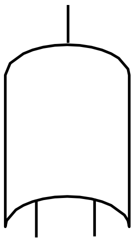
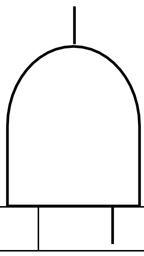
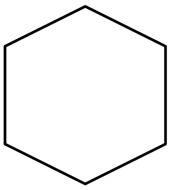
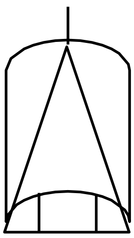
According to Sjarifudin et al. (2023), fault tree analysis is a reliable method for reducing unwanted failures by drawing conclusions and using visual aids. One type of diagram used to connect information in examining failure mechanisms and their impacts is the FTA, a one-way diagram.

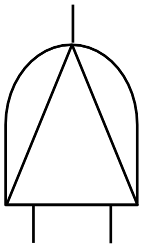
Table 1. Event Symbols

No	Symbol	Symbol Description
1	Basic event 	This circle symbol is used to represent a basic event or primary event, or a fundamental failure for which no cause needs to be investigated. This means that the circle symbol represents the final limit of the cause of an event.
2	Undeveloped event 	This diamond symbol is used to represent an undeveloped event, or an event that cannot be further developed. This is a specific failure event for which no further cause is sought, either because the event is not sufficiently related or because no related information is available, making it the final event of a problem that occurs in a study.
3	Conditioning event 	This oval symbol is used to represent a conditioning event, which is a special condition or limitation applied to a gate (usually the INHIBIT and PRIORITY AND gates). Thus, an output event occurs if an input event occurs and satisfies a specific condition.
4	External event 	The house symbol is used to represent an external event, which is an event that is expected to occur normally and is not considered a failure event.

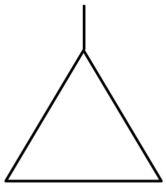
5	Intermediate event 	This rectangle symbol contains an event that arises from a combination of failed input events entering the gate.

Table 2. Gate Symbols

No	Symbol	Symbol Description
1	OR Gate 	The OR gate is used to indicate that an event will occur if one or more of its input events fail to occur.
2	AND Gate 	The AND gate is used to indicate that an output event occurs only if all input events occur.
3	INHIBIT Gate 	The INHIBIT gate, symbolized by a hexagon, is a special case of the AND gate. The output is caused by a single input, but a specific condition must be met before the input can produce an output.
4	EXCLUSIVE OR Gate 	The EXCLUSIVE OR gate is an OR gate with a specific case where the output event occurs if one event also occurs.

5	PRIORITY AND Gate 	The PRIORITY AND gate is an AND gate with a condition where the output event occurs only if all input events occur in a specific order.

Tabel 3. Transfer Symbol

No	Symbol	Symbol Description
1	*Transfer-in* 	Triangle-in or transfers-in, the point where a sub-fault tree can start as a continuation of transfers out.

According to Nurwulan & Veronica (2020), before a system, design, process, or service is delivered to a customer, known failures, problems, errors, and similar issues are identified, discovered, and eliminated using the FMEA engineering approach. FMEA is used to identify the source and root cause of quality issues. Severity (S), Occurrence (O), and Detection (D) are used to calculate the Risk Priority Number (RPN), a number that indicates the risk priority obtained by multiplying these three factors. RPN = S * O * D

Table 4. Severity

Rating	Criteria	Description
1	No effect	Customer unaware of defect
2	Very mild	Minor defect, only detected by experienced inspector
3	Mild	Slightly disturbed by customer, does not affect product function
4	Mild-moderate	Slight reduction in visual quality, still acceptable
5	Moderate	Customer dissatisfied, visual quality reduction is quite noticeable
6	Moderate-high	Customer complains, some products require rework
7	High	Product rejected, cannot be sold as grade A quality
8	Very high	Product completely rejected, customer return claim
9	Critical	Loss of customer trust, potential order cancellation
10	Very critical	Involves safety/regulations or significant customer loss

The first step in analyzing risk is severity, which determines the extent to which an event impacts the outcome of a process. On a scale of 1 to 10, 10 represents the worst possible impact and is used to determine the severity of that impact (Gupta, 2023).

Table 5. Occurrence (Event Rate)

Rating	Criteria	Description
1	< 0.01	Almost never (very rare)
2	0.01 - 0.1	Very rare
3	0.1 - 0.5	Rarely occurs
4	0.5 - 1	Occasionally occurs, still under control
5	1 – 3	Fairly frequent
6	3 – 5	Frequently occurs, starting to be a concern
7	5 - 10	Frequently occurs, requires action

Rating	Criteria	Description
8	10 - 20	Very frequent
9	20 - 50	Almost always occurs under certain conditions
10	> 50	Chronic defect / almost certain to occur

The occurrence rating must be verified to ensure that it has been assigned to all severity phases. A potential failure cause that occurs and causes a specific type of failure during the product production phase is referred to as an event.

Table 6. Detection

Rating	Criteria	Description
1	Very high	100% automatic control detects defects before further processing
2	High	Automatic inspection with large sampling, highly reliable
3	Fairly high	Structured manual inspection with standard checklists
4	Medium-high	Routine manual inspection but not yet fully standardized
5	Medium	Manual sampling inspection, dependent on operator experience
6	Medium-low	Unscheduled inspection, only when complaints arise
7	Low	Limited control, relying on individual operator awareness
8	Very low	Almost no detection control at this stage
9	Almost undetectable	Defects are only discovered after the product is in the customer's hands
10	Undetectable	No detection mechanism at all

After obtaining the severity, occurrence, and detection values associated with defects in window products, the RPN value is calculated by multiplying these three values (RPN = S x O x D). The results are then arranged in order of RPN value from highest to lowest. Next, recommendations for improvement are provided to production process activities that play a crucial role in a production process and have high RPN values, so that the number of product defects can be reduced.

A Pareto chart is a scheme created in the 19th century by Vilfredo Pareto, an Italian economist (Arif et al., n.d.). A Pareto chart refers to a black and white image that shows how each type of data compares to a grand total. A Pareto chart helps us identify the biggest problems so we can focus on finding solutions. The purpose of a Pareto chart is to create a master matrix that serves to improve quality by ordering items from largest to smallest. The distribution of data variables is displayed in this chart. Pareto charts are typically used to identify the most critical problems. The 80/20 rule states that 20% of errors or mistakes can cause 80% of process failures. This rule can be demonstrated in a Pareto chart (Yunita et al., 2025). This diagram is used to group events into priority categories, so that the cumulative value can help identify the most influential factors.

The data used in this study were data on production and the types of defects occurring in rayon fiber, obtained through direct observation at the production site. This data included the number of production outputs and production defects collected monthly. According to (Tyas et al., 2025), data processing was carried out using the Fault Tree Analysis (FTA) method to identify the root causes of problems that lead to product defects. After that, the process continued with finding corrective solutions through Failure Mode and Effect Analysis (FMEA). The first step in this study was using FTA to identify the relationships between causal factors and display them in the form of a fault tree. According to (Rizky Dwi Hardianto1, 2023), fault tree analysis is one method used to identify the root causes of work failures. This method uses a top-down approach, starting with the assumption of a primary event failure, then analyzing the causes until the root cause of the failure is reached. This primary event is the undesirable event or the one whose cause is being investigated. Furthermore, after the primary event, there will be other events called fault events. Using FTA, factors that contribute to failure can be identified, thus affecting the process and resulting product.

The second method is FMEA, which is a method used to evaluate failures that occur in a system, design, process, or service. Potential failures are identified by assigning a value or score to each failure mode based on the likelihood of occurrence, the extent of damage, and the ease of detection. The calculation is performed using a ranking value that indicates the condition of damage to the machine during the production process (Aldi Wicaksono, 2023). The Risk Priority Number (RPN) is a method for measuring risk levels relatively. The RPN is determined before implementing repair recommendations; it is used to determine which part of the failure is the highest priority. The RPN is obtained by multiplying Severity, Occurrence, and Detection. Based on known risks, the RPN value for each component can be used to determine the critical risk value. These risks will be further analyzed as the initial step in taking action to address them, thereby maintaining machine performance. A risk is considered critical if its RPN value is higher than the critical RPN value. The critical RPN value is determined based on the average RPN value of all existing risks (Alifka & Apriliani, 2024).

C. RESULTS AND DISCUSSION

The findings and analysis in this study are based on observations, interviews with sources, and data from various literary works. Production workers were selected as sources to complete questionnaires and participate in interviews. Risks that arise during the production process were identified by observing and asking relevant people. Afterward, risks were assessed by answering several questions regarding the incident, its severity, and how the incident was detected. The identification process using the FTA and FMEA approaches yielded the following results. The following are statistics on defective production from June 2025 to May 2026:

Table 7. Summary of T-Shirt Product Defect Data

Month	Production Quantity	Type of Defect			Number of Defective Products	%
		Sewing	Imprecise Screen Printing	Cutting		
June	1156	44	32	22	108	9.3%
July	1440	49	44	23	119	8.3%
August	1970	61	37	24	122	6.2%
September	1535	53	44	28	125	8.1%
October	1479	52	47	25	124	8.4%
November	1678	38	47	18	103	6.1%
December	1820	52	41	20	113	6.2%
January	1320	58	44	22	124	9.4%
February	1280	51	43	26	130	10.2%
March	1450	49	42	27	121	8.3%
April	1610	56	43	21	110	6.8%
May	1740	45	52	19	106	6.1%
Total	**18478**	**608**	**516**	**275**	**1399**	93,5%
Percentage of Defects		**43%**	**37%**	**20%**		
Mean	**1,540**	**51**	**43**	**23**	**117**	**7.8%**

Total t-shirt production in 12 months was 18,478 pieces, and the number of imperfect products reached 1,399 pieces. The most common type of defect was sewing defects with 608 pieces, followed by imprecise screen-printing defects with 516 pieces, and cutting defects with

275 pieces. The highest percentage of defects occurred in February at 10.2%, while the lowest percentage occurred in November and May at 6.1%, respectively.

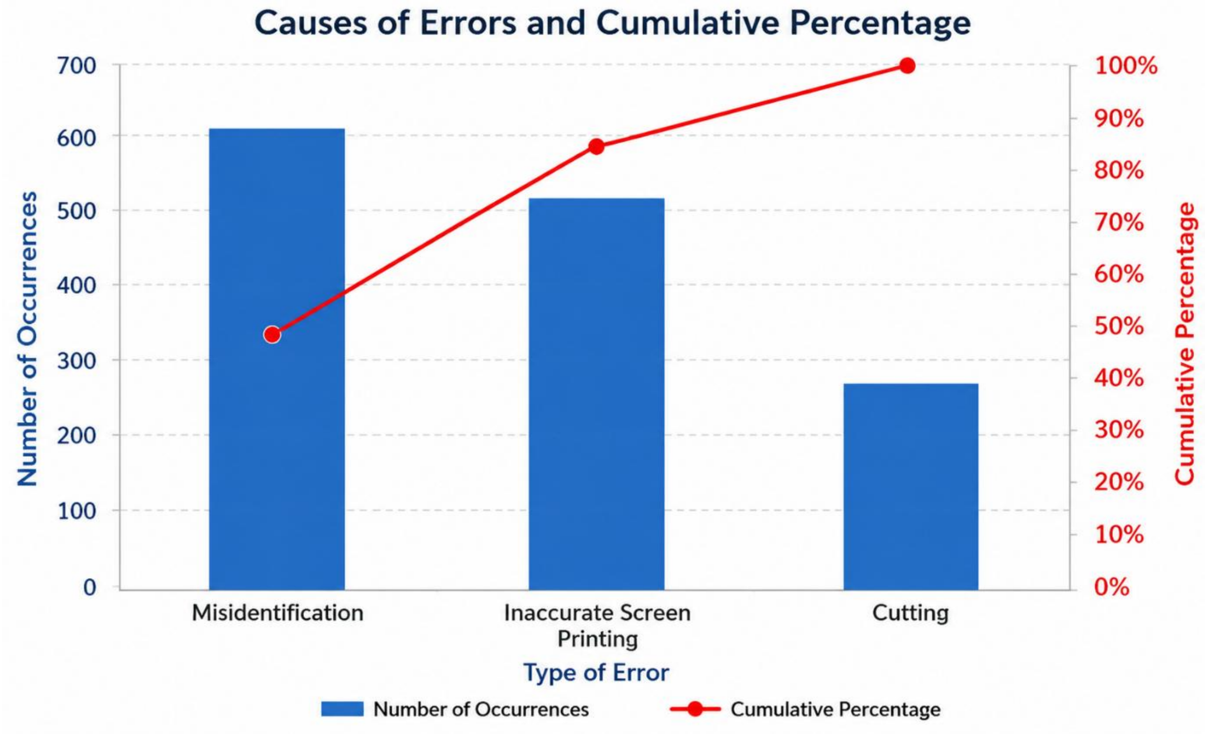


Figure 1. Pareto Diagram of T-Shirt Product Defect Types

The Pareto diagram shows three main issues that contribute to product defects. To reduce the number of defective products, improvements are needed, particularly in the most common types of defects. Based on the 80%/20% principle, the main issues causing product defects are sewing errors and screen-printing errors.

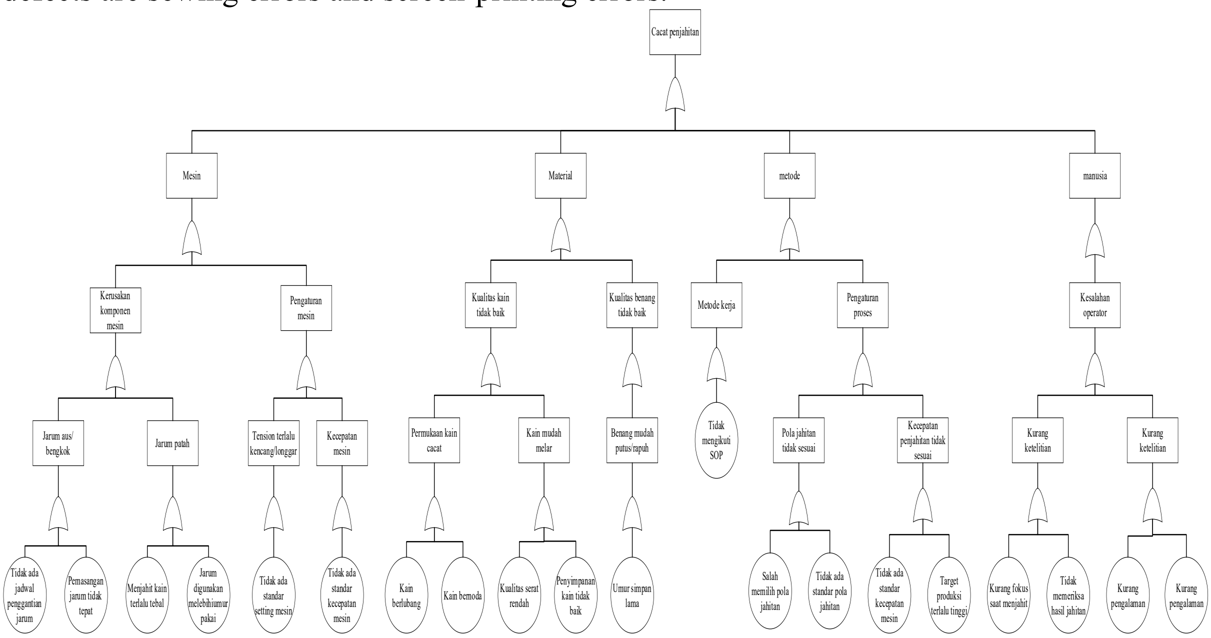


Figure 2. Fault Tree Analysis of Sewing Defects

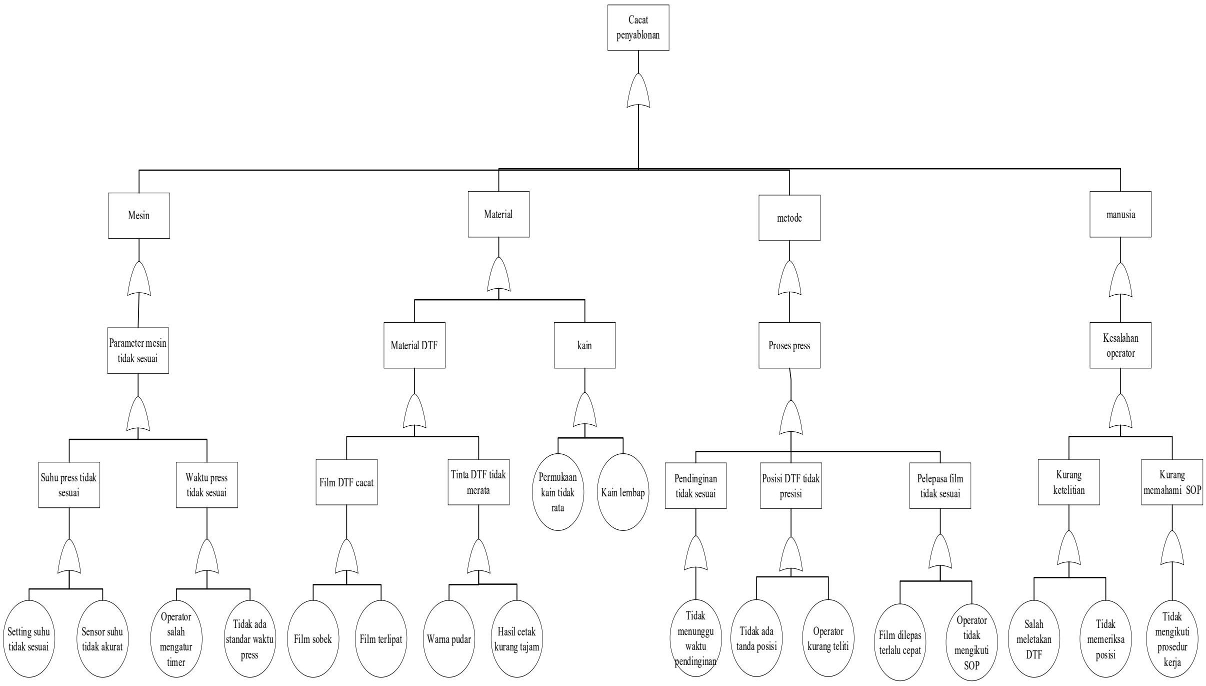


Figure 3. Fault Tree Analysis of Screen-Printing Defects

Table 8. Faiure Mode and Effects Analysis (FMEA)

Failure Mode	**Factor**	**Potential Cause**	**Potential Effect**	**Current Control**	**S**	**O**	**D**	**RPN**
Sewing	Human	Lack of focus while sewing	Uneven stitching, deviating from the pattern	Periodic supervision by supervisor	6	6	6	216
		Not checking stitches	Defects pass through to the next process	Self-inspection after sewing	6	5	7	210
		Lack of work experience	Sewing technique is unstable, results are inconsistent	Mentoring of new operators by senior operators	5	5	5	125
		Lack of training experience	Operators do not understand sewing technique standards	Basic training before starting work	5	4	5	100
	Method	Not following SOPs	Sewing process is inconsistent between operators	Socialization & monitoring of SOP compliance	6	5	6	180
		Wrong sewing pattern selection	Stitches do not match the design, resulting in rejected products	Pattern verification before mass production	7	6	4	168
		No standard sewing pattern	Pattern variations between operators, resulting in inconsistent results	Preparation of written sewing pattern standards	6	6	5	180
		No standard machine speed	Sewing speed is inconsistent, stitching is imprecise	Setting speed standards according to fabric type	6	6	4	144
		Production target too high	Operators are in a rush, resulting in decreased stitch quality	Evaluation of production targets according to normal capacity	6	7	6	252
	Material	Fabric with holes	Defects are visible on the surface of the finished product	Incoming fabric quality check	6	3	2	36

Failure Mode	Factor	Potential Cause	Potential Effect	Current Control	S	O	D	RPN
		Stained fabric	Product looks dirty/visually defective	Incoming fabric quality check	5	3	2	30
		Low fiber quality	Fabric stretches easily during sewing	Supplier selection & fiber quality check	5	4	3	60
		Poor fabric storage	Fabric stretches/is damp before processing	Improving storage systems (temperature & humidity)	5	4	4	80
		Long thread shelf life	Thread is fragile, easily breaks during sewing	Checking thread stock dates & conditions (FIFO)	5	4	2	40
	Machine	No needle replacement schedule	Worn/bent needle, skipped stitches/holes	Preparing a periodic needle replacement schedule	6	5	3	90
		Incorrect needle installation	Worn/bent needle, resulting in untidy stitching	SOP for needle installation before production	6	4	3	72
		Sewing fabric that is too thick	Needle breaks during sewing	Adjusting needle type to fabric thickness	6	3	4	72
		Needles used beyond their intended lifespan	Needle breaks, production stops	Monitoring service life & preventive replacement	6	5	3	90
		No standard tension setting	Tension is too tight/loose, stitches are loose/wrinkled	Determining machine tension setting standards	5	5	4	100
		No standard machine speed	Machine speed is inconsistent, stitching is imprecise	Determining speed standards according to SOP	6	5	4	120
Screen Printing (DTF)	Human	Incorrect placement of the DTF	Skewed/off-center design on the product	Use of positioning aids/jigs	7	5	4	140
		Not checking position	Off-center design, resulting in rejected products	Position verification before pressing	6	5	6	180
		Not following work procedures	Pressing process is inconsistent between operators	Socialization & monitoring of SOP compliance	6	5	6	180
	Method	Not waiting for cooling time	DTF film fails to adhere properly, resulting in Faded	Implementation of standard waiting times before film removal	6	5	5	150
		No position markings	DTF position shifts during transfer	Creating positioning marks/jigs on the work table	6	5	5	150
		Operator carelessness	DTF position is imprecise, design is skewed	Supervision & operator accuracy training	6	5	5	150
		Film removed too quickly	Design does not adhere properly, some parts peel off	Implementation of standard waiting times before release	6	5	5	150

Failure Mode	Factor	Potential Cause	Potential Effect	Current Control	S	O	D	RPN
		Operator not following SOPs	Damaged/imperfect printouts	Socialization & monitoring of film release SOPs	6	4	6	144
	Material	Film torn	Design is incompletely transferred, product is rejected	Proper handling & storage of DTF film	6	3	2	36
		Film folded	Damaged/uneven printouts	Storing DTF film in a flat/neat condition	6	3	2	36
		Colors faded	Prints are less sharp/pale	Checking DTF ink quality before use	5	4	3	60
		Print results less sharp	Product visual quality decreases	Checking film print quality before pressing	5	4	3	60
		Fabric surface uneven	Press results do not adhere properly	Incoming fabric inspection (incoming quality check)	6	4	3	72
		Fabric damp	DTF adhesion decreases, peels easily	Storing fabric in dry and controlled conditions	6	4	3	72
	Machine	Incorrect temperature setting	DTF does not adhere properly/burns	Calibration & monitoring of press machine temperature	6	5	3	90
		Inaccurate temperature sensor	Actual temperature deviation, inconsistent results	Scheduled temperature sensor calibration (preventive maintenance)	6	4	4	96
		Operator incorrectly set timer	Press time is less/more than standard	Use of automatic timers according to standards	6	4	3	72
		No standard press time	Press time is inconsistent between operators	Establishment of written press time standards	6	5	4	120

Table 9. Failure Mode and Effects Analysis Simulation After Repair

No	Failure Mode	Reason	Corrective Action (How)	PIC (Who)	Initial RPN	S	O	D	New RPN	Degradation
1	Sewing	Production targets are too high	Evaluate and re-establish production targets according to normal operator and machine capacity.	Production Manager / PPIC & Supervisor	252	6	3	4	**72**	71%
2	Sewing	Lack of focus while sewing	Regular supervision by supervisors and adequate rest periods.	Production Supervisor	216	6	3	4	**72**	67%
3	Sewing	Not checking stitches	Mandatory self-inspections after sewing, accompanied by	Sewing Operator & QC	210	6	4	3	**72**	66%

			a visual checklist.							
4	Sewing	Not following SOPs	Periodic re-socialization of SOPs and routine compliance audits.	Production Supervisor	180	6	3	4	**72**	60%
5	Sewing	No standard sewing patterns	Develop and document written sewing pattern standards as a shared reference.	QC/Engineering Team & Supervisor	180	6	3	3	**54**	70%
6	Screen Printing (DTF)	Not checking position	Mandatory position verification before pressing, using a positioning jig.	Screen Printing/DTF Operator	180	6	3	3	**54**	70%
7	Screen Printing (DTF)	Not following work procedures	Routine socialization and regular monitoring of SOP compliance.	DTF Operator & Supervisor	180	6	3	4	**72**	60%
8	Screen Printing (DTF)	Not waiting for cooling time	Implement standard waiting times before film removal, using a timer.	Screen Printing/DTF Operator	150	6	2	3	**36**	76%
9	Screen Printing (DTF)	No position markings	Establish permanent positioning jigs on work tables.	Engineering Team	150	6	2	2	**24**	84%
10	Sewing	Operator is not careful	Operator accuracy training and routine supervision by supervisors.	DTF Operator & Supervisor	150	6	3	4	**72**	52%

D. CONCLUSION

Based on the research results, Pareto Diagram, Fault Tree Analysis (FTA), and Failure Mode and Effect Analysis (FMEA) are very effective in identifying types of defects, root causes of problems, and determining the priority order for improvements in the T-shirt production process at CV Dwiputra Ihwa. Defects in sewing (43%) and inappropriate screen printing (37%) are the main causes of products that do not meet standards. The cause with the greatest risk is excessively high production targets (RPN 252). Proposed improvements such as evaluating production targets, increasing compliance with SOPs, self-inspections, training for operators, and stricter supervision are expected to reduce the level of defects, improve quality, and make the production process more efficient.

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