RISK ANALYSIS IN SANDWICH PANEL PRODUCTION WITH THE INTEGRATION OF FMEA AND FTA METHODS

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ABSTRACT

General Background: Ensuring consistent product quality is crucial for maintaining competitive advantage, especially in manufacturing. PT. Starr Panel Industry, a company in the refrigeration sector, focuses on high-quality sandwich panels but experiences frequent defects in its production processes. **Specific Background:** Despite prioritizing premium raw materials, the company faces recurring product failures, particularly in the finishing phase, which affect production flow and on-time delivery. **Knowledge Gap:** Current quality assurance measures at PT. Starr Panel Industry lack a systematic approach to identifying and prioritizing the root causes of defects, hindering the development of targeted improvement strategies. **Aims:** This study aims to identify, analyze, and address potential failure modes and their root causes within the production processes, employing Failure Modes and Effects Analysis (FMEA) and Fault Tree Analysis (FTA). **Results:** The findings reveal that the finishing process has the highest Risk Priority Number (RPN) of 112, primarily due to insufficient adherence to standard operating procedures (SOPs) by the workforce. **Novelty:** The integration of FMEA and FTA provides a comprehensive failure analysis model, with FMEA ranking failure risks and FTA tracing them to foundational causes, offering a new dual-method approach to improve operational standards effectively. **Implications:** Implementing the proposed FMEA-FTA framework can significantly reduce product defects, improve quality consistency, and minimize delivery disruptions, especially in the critical finishing stage. Emphasizing SOP compliance across divisions, particularly in finishing, can lead to sustained quality improvements and enhanced operational efficiency in sandwich panel production.

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INTRODUCTION

Quality is the main factor that consumers consider before deciding to buy a product [1]. Quality is the main aspect of a product because quality can be a benchmark for the level of buyer satisfaction, therefore it is very important for companies to improve product quality. By being the main aspect, it makes companies have to make efforts to improve product quality standards in the hope of achieving a product defect level that almost reaches zero or called zero defect [2]. In the midst of modernization and fierce competition in the world industry, all companies want to have good product quality and be able to compete in the era of globalization.

Based on previous research, it was found that quality problems experienced by companies resulted in product failures in the form of scratches on plates that were caused in the process roll press during the production process [3]. A similar condition is experienced by PT Starr Panel Industri, the rate of defects reached in the last 3 months by 21%, this resulted in 2 customer complaints every month, therefore a defect mitigation strategy is needed in the sandwich panel production process.

The research can be carried out to analyze the causes of quality problems that occur in panel sandwiches with the Failure Modes and Effect analysis (FMEA) as a prevention of product defects. Failure Modes and Effect analysis (FMEA) is an approach used to assess failures that occur in a system, design, process, or service [4]. Assisted by a flow process map, we can find out what failures can occur during the production process. After knowing what failures the company has gotten, the company can analyze the failure by providing a value or rank on each failure with reference to the standard RPN value (Risk Priority Number) [5].

Before evaluating the failure with the Failure Modes and Effect analysis (FMEA) can be analyzed for the root cause of failure using the Fault Tree Analisys (FTA). FTA is a technique used to identify risks or find the root cause of the problem that causes the failure with the FTA method can be used to create a fault tree by analyzing the peak of the failure (top event) Then it is described with the causes from failure to basic failure (root cause) [6]. This analysis aims to identify and understand the risk of potential failure modes as well as the causes and impacts of failure on products or production processes. The scope of this study is to identify risks, determine risk priorities and develop risk mitigation strategies that aim to reduce the occurrence of defect products using the Failure Modes and Effect analysis (FMEA) then Fault Tree Analisys (FTA). The results of this research are expected to improve the quality of products at PT. Starr Panel Industry and can be developed by other companies.

METHODS

The research method was obtained from the results of observation by analyzing the production flow process, the results of the interviews included production admins, SPVs, and production managers to identify product failures using the FMEA and FTA methods, and also distributed questionnaires to participants, among others *leader* mesin decoiler & roll forming, *leader* PU machine *injection*, *leader* machine *cutting*, *leader finishing*. *Failure Modes and Effects Analysis* (FMEA) is defined as a structured way to identify the causes of hazards that exist in product quality and root cause of problems and as many failure modes as possible (*failure mode*) with the handling steps [7]. The FMEA also prioritizes causes with *rank* Most superior, reduce the problems of the production system. This method aims to find proposed recommended actions used to overcome the causes of production failure or *waste*.

Method *Failure Modes and Effects Analysis* (FMEA) conducted an analysis by means of a systematic approach and applied a level of rationality in risk ranking by considering three factors, namely severity (*severity),* event *(dccurrence),* detection *(detection)* [8]. In the data processing of this study, the method of *Failure Modes and Effects Analysis* (FMEA) conducts an analysis by means of an assessment on each cause of production failure or called the RPN calculation with a value of 1-10. The determination of the value needed to calculate the RPN comes from *severity* (S), *occurance* (O), from *detection* (D) [9]. The following is the formula for RPN:

RPN = O x S x D [10].

RPN is a value that refers to the priority level of each failure by determining *rank* highest on the cause of failure. From *rank* The company can find out where the highest risk that causes failure lies. The value of RPN comes from 3 components, including *Severity* (severity), *Occurance* (incidence rate), *Detection* (detection method). With the probability of failure value, this approach can identify the components that are most likely the cause of failure. Value *Severity* It is measured on a scale of 1 to 10 where the value of 1 shows the lowest value to the value of 10 shows a very serious impact. Value *Occurrence* It is measured on a scale of 1 to 10 where a value of 1 indicates the lowest value to a value of 10 indicates that failure is most likely to occur. Value *Detection* Measured on a scale of 1 to 10 with a value of 1 indicating that failure can be easily detected to a value of 10 indicating that failure is difficult to detect [11].

The table below is the score of the *Severity, Occurrence, Detectability* in order to get RPN scores.

Table 1. Value *Severity, Occurrence, Detection* [12].

Severity	*Occurrence*	*Detection*	Rating
None	Almost impossible	Almost certainly	1
Very small	Irrelevant	Very high detection	2
Minor	Low	High detection	3
Low	Relatively low	Availability is quite high	4
Keep	Keep	Medium detection	5
Important	Quite high	Low detection	6
Big	Tall	Very low detection	7
Extreme	Repeated failures	Remote detection	8

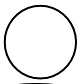
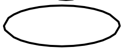
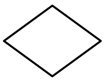
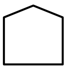
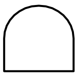
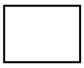
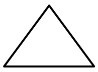
Serious	Very high	Ultra-remote detection	9
Dangerous	Very high	Absolute uncertainty	10

The following are the steps in conducting an analysis using the FMEA method:

a. Determine the cause of failure by racing the production process.
b. Determine the *occurrenceance*, *severity*, and *detection* *values* for each cause of failure by racing against the standard values of the table.
c. Recap *the occurrence*, *severity*, and *detection* assessments to generate RPN (*Rank Priority Number*) values.

After analyzing the cause of failure using the FMEA method, it can then be analyzed using the *Fault Tree Analisys* (FTA) in order to get maximum improvement proposals. Method *Fault Tree Analisys* (FTA) is a graphical model that is applied as an analytical approach that is *Top Down* which is meant by the prefix of the failure assumption of *top event* which is further detailed until it comes to the fundamental failure or called *root cause* [13]. The symbols used in the FTA analysis are as follows:

Table 2. Symbols in FTA Analysis [14].

Symbol	Meaning
	*Basic events*, initiation basics, errors.
	*Conditioning event*, specific conditions.
	*Undevelopment event*, a condition that cannot be developed.
	*External event*, the expected condition appears.
	*AND logic events* , manual error conditions due to all inputs being incorrect.
	*Logic event* OR, an error condition due to one of the problematic inputs.
	*Top event*, a condition that shows failure that will be studied again.
	*Transferred event, the* event condition is different from other pages.

Here are the steps in conducting an analysis using the FTA method [15]:

1. Determine the cause of the failure.
2. Create a graphical model of the error tree from the cause of failure.
3. Determine the cause of the smallest failure of the error tree analysis.
4. Make a proposal for improvement.

In this study, there are several flows that are used as a reference for the research process, which can be seen in the figure below.

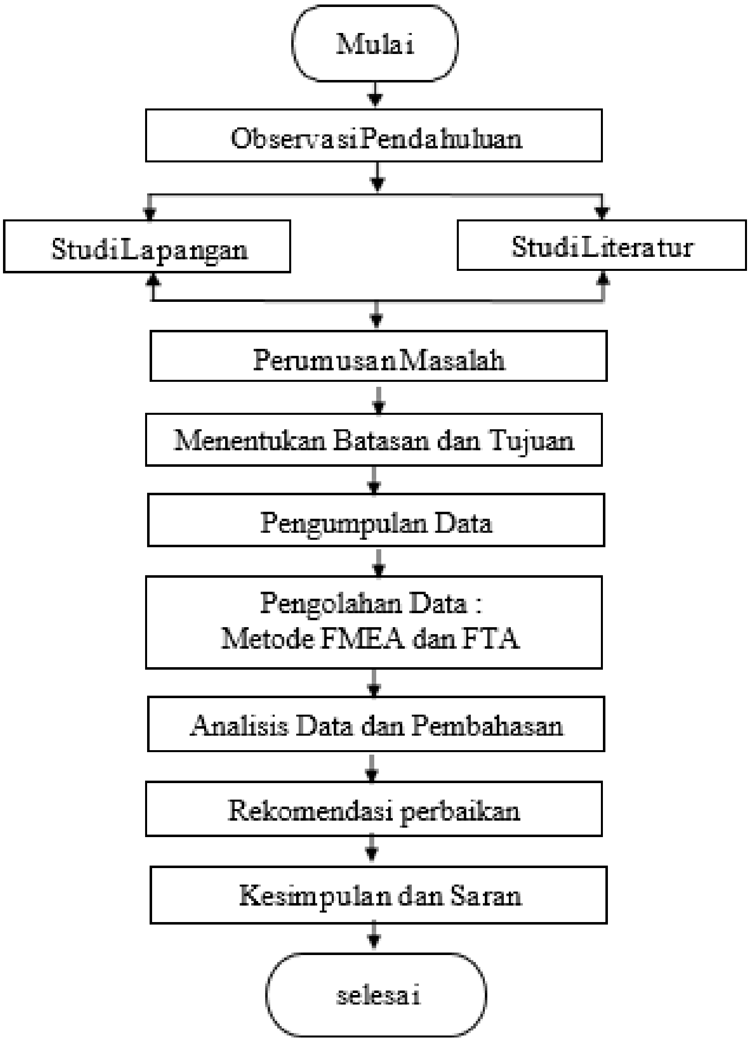


Figure 1. Research Flow

In figure 1, the research flow used in the research of PT. The Industrial Starr Panel which has stages includes: (1) making observations (2) formulating problems (3) determining the limits and objectives of the research (4) collecting data (5) processing risk analysis data using the FMEA method (6) making recommendations for improvement using the FTA method (7) making conclusions and suggestions.

RESULT AND DISSCUSION

Based on the production flow process, the panel sandwich describes the flow from the beginning of the production process to *the finishing* process, it can be known *what deffects* occur in the panel sandwich production process. The data on the causes of *this deffect* is then analyzed so that RPN values can be found based on occurrence, *severity*, and *detectability analysis*. Data was obtained from direct observation results to the production area with the following table results:

Table 3. Data on the number of failures for July – December 2023.

It	Process	July 2023		August 2023		September 2023		October 2023		November 2023		December 2023	
		Production Qty	Qty failed product	Production Qty	Qty failed product	Production Qty	Qty failed product	Production Qty	Qty failed product	Production Qty	Qty failed product	Production Qty	Qty failed product
1	*Decoiler*	550	5	600	5	600	5	550	5	500	5	550	5
2	*Roll forming*	550	5	600	5	600	5	550	5	500	5	550	5
3	PU injection	550	40	600	50	600	60	550	55	500	50	550	60
4	*Cutting*	550	10	600	10	600	15	550	10	500	10	550	20
5	*Finishing*	550	30	600	40	600	55	550	50	500	40	550	50
	Total		90		110		140		125		110		140

(Source; PT. Starr Industrial Panel).

Table 3 above shows that production QTY and product QTY failed from July to December 2023.

Table 4. Average failure data.

No	Period	Production Quantity	Number of failed Products
1	July 2023	550	90
2	August 2023	600	110
3	September 2023	600	140
4	October 2023	550	125
5	November 2023	500	110
6	December 2023	550	140
	Total	3350	715

(Source; PT. Starr Industrial Panel).

Average = number of product failures / number of products
= 715 / 3350
= 21%

Based on data from table 4, the average product failure from July 2023 to December 2023 reached 21%. The failure data exceeded the tolerance standard limit of 100 Pcs sandwich panels per month. The number of failed products in July still reached the company's tolerance limit, but from August to December the number of product failures exceeded the tolerance limit given by the company. Furthermore, it can be analyzed what are the causes of the product failure using the FMEA method. The following is a table of production locations, production activities, potential failures, the impact of failures and RPN values.

Table 5. FMEA analysis.

No	Location	Activity	Potential for Failure	Impact of Failure	Or	S	D	RPN
1	Machine *decoiler*	1. Weighing coil	Wrong weight of coil	Occurrence of coil picking errors and cause waste of time	2	2	8	32
		2. Inserting the coil on the machine	Entering the wrong coil type	The occurrence of material waste and product rejection	3	2	6	36
2	Mesin *roll forming*	1. Print the coil according to the preset shape.	Missetting the mold shape.	The occurrence of waste and causes reproduction.	3	2	8	48
		2. Cleaning the conveyor.	The area is not sterile.	Resulting in the plate becoming marking.	4	5	2	40
3	PU *Injection*	1. The process of dispensin g foam liquid.	Non-compliant material dosage settings and expired material escape .	Causing the produced panels to be rejected and making *the finishing* process overloaded.	5	7	3	105
		2. Check the muld regularly.	Muld does not form perfectly.	The resulting panel profile does not conform to the size standard.	3	3	3	27
4	Machine *cutting*	1. Automatic cutting on the panel	Break of the saw band in the panel cutting process	Causes the panel not to cut with Maximum	2	2	7	28
		2. Periodic checks on the monitor screen.	Incorrect size in the cutting process.	Causing the panel to be included in the second grade category so that it has to reproduce the panel job	2	3	9	54
5	*Finishin g*	1. *Panel* cleaning finishing.	Passing the panel that is not clean	Unable to meet the delivery schedule so there	7	8	2	112

			was a delay.				
2.	Check the standard panel.	Passing panels that are not in accordance with company standards	The panel will be returned by the user resulting in waste on shipping costs and materials	3	4	2	24

(Source: PT. Starr Industrial Panel).

Tabel 6. *Risk Priority Number* (RPN).

No	Location	Activity	Or	S	D	RPN	*Rank*
1	*Finishing*	1	7	8	2	112	1
2	PU *Injection*	1	5	7	3	105	2
3	Mesin *cutting*	2	2	3	9	54	3
4	Mesin *roll forming*	1	3	2	8	48	4
5	Mesin *roll forming*	2	4	5	2	40	5
6	Decoiler *machine*	2	3	2	6	36	6
7	Decoiler *machine*	1	2	2	8	32	7
8	Mesin *cutting*	1	2	2	7	28	8
9	PU *Injection*	2	3	3	3	27	9
10	*Finishing*	2	3	4	2	24	10

(Source: PT. Starr Industrial Panel).

From the results of table 10, the RPN value ranking was obtained from the production location that caused the largest to the lowest failure. In the *finishing* process, it has the highest RPN value of 112 caused by activity 1. 2nd ranking with an RPN value of 105 at the location of PU *injection* caused by activity 1. The 3rd ranking with an RPN value of 54 caused by the cutting machine operator in activity 2. *The* 4th RPN rank of 48 is caused by the roll forming machine operator in activity 1. The 5th rank is caused by the *roll forming machine* in activity 2 with an RPN value of 40. In the decoiler machine process caused by activity 2 produces a value of 36 with the 6th rank. In the *decoiler* process caused by activity 1, it has an RPN value of 32 with a 7th rank. In the *cutting* process caused by activity 1, it has an RPN value of 28 so it is ranked 8th. At rank 9 it is caused by the location of PU *injection* with an RPN value of 27. For the lowest, namely *rank* 10 is caused by the finishing location in activity 2.

Fault *Tree Analysis* (FTA) analysis data is obtained from an error tree with a visual analysis of the sandwich panel production process that results in product failure. You can see from the error tree graph in figure 1 below.

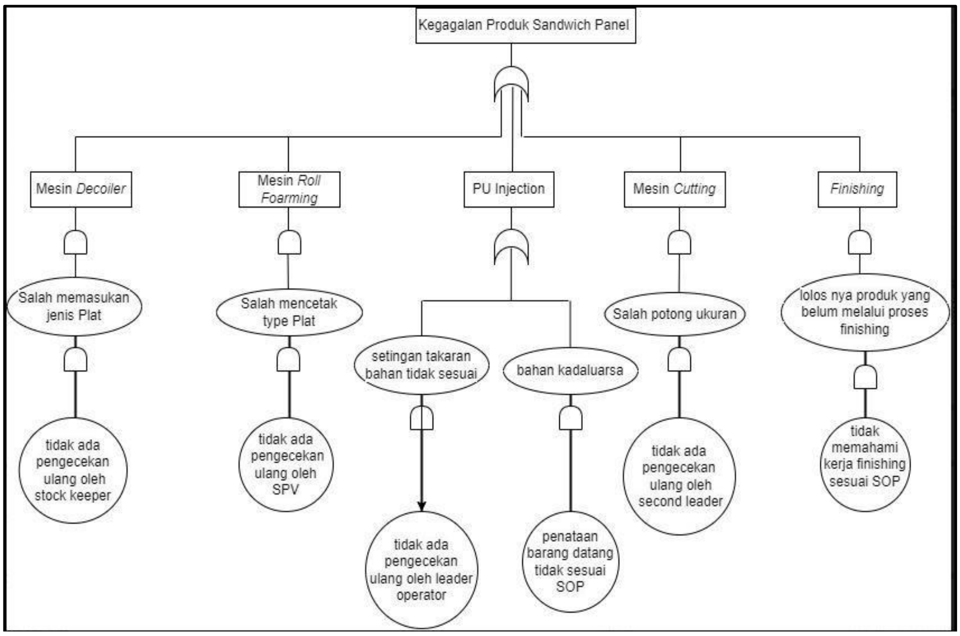


Figure 2. FTA analysis (source; PT. Starr Industrial Panel).

Based on the results of FMEA and FTA, it can be known *the* ranking of the causes of product failures and *defects*, so from these results, improvement proposals can be recommended to overcome the causes of failure. From the results of the FMEA and FTA methods, improvements can be made from the production process such as emphasizing production operational standards to each operator and improving several production operational standard flows that need to be improved in order to improve the quality of existing products and not cause many failures that have an impact on waste.

CONCLUSION

Fundamental Finding: This study identifies critical failure modes in the sandwich panel production process at PT. Starr Panel Industry, with the finishing phase exhibiting the highest Risk Priority Number (RPN) of 112. The main issue in this phase is insufficient adherence to standard operating procedures (SOPs), resulting in delays and increased defect rates. **Implication:** The integration of FMEA and FTA enables a dual-method approach to failure analysis that improves product quality by pinpointing high-risk areas and their root causes, particularly in the finishing process. This approach supports operational standardization and process optimization, essential for reducing defect-related losses and enhancing production efficiency. **Limitation:** The research is limited to the production processes specific to PT. Starr Panel Industry and may not fully address other contextual factors such as external supplier quality or machine maintenance schedules that could impact product quality. **Further Research:** Future studies should extend this dual-method approach to analyze supplier quality control and preventive maintenance strategies to gain a more comprehensive understanding of factors influencing defect rates in production.

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