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Analysis of Furniture Product Defects Using Fault Tree Analysis and Root Cause Analysis Methods

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Abstract

PT WW is a furniture company that uses teak wood as its main material. Factory 1 often experiences product defects because it handles the initial production stage. This study focuses on the SP-15 chair, the company's best-selling product, which has a defect rate of 15.2%, far above the company tolerance of 5%. The research aims to reduce these defects using the Fault Tree Analysis (FTA) method and provide improvement recommendations. Observations revealed three defect categories with eleven basic causes. The most dominant defect is rupture, with 2726 units and a probability of 0.0085 or 0.85%. Meanwhile, the lowest defect type is incorrect process, with 835 units and a probability of 0.0034 or 0.34%. Because rupture has the highest probability, improvement efforts are urgently needed. Proposed corrective actions include developing and applying SOPs for wood processing, installing visual guides in the work area, establishing standard work procedures, and providing short operator training. Additional recommendations include routine technical training and competency tests, guidelines for machine pressure settings based on wood type, and operator instruction on adjustment. Regular maintenance schedules should also be established, with visual operation guides placed near machines to ensure operators follow correct steps. These efforts are expected to reduce defects and improve the quality of SP-15 chair production at PT WW.

Introduction

The furniture industry in Indonesia is one of the rapidly growing business processes in the global market that is in great demand by consumers in various countries. The type of wood that is of high quality and durable makes furniture with natural raw materials attractive to consumers. In addition to the use of raw materials, companies also need a strategy for the furniture production process (Rahmawati & Scholastika, 2023; Skorupińska et al., 2024; Hartini et al., 2021; Lins et al., 2021). The furniture production process involves several stages starting from the selection of raw materials, cutting, assembly to finishing. Each stage has the potential for failure or defects that can affect the quality of the final product. So effective quality control is needed to identify, prevent, and resolve quality problems that occur (Chen et al., 2024; Rame et al., 2023; Wieruszewski et al., 2023).

According to Ashari & Yohanes (2022) Quality control is important and closely related to the production process, where each activity includes the activity of checking or testing the quality characteristics of the product. Product quality demands have changed over time. Now product quality is the main thing in production to meet consumer needs according to the specifications and quality standards that have been set (Shcherbakov et al., 2022; Yoji, 2024; Liu et al.,

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2023; Burgess et al., 2022). Quality problems that often occur in the production process are product defects. Product defects not only have a negative impact on customer satisfaction, but can also result in financial losses for the company due to the cost of repairs and product returns. The company must find a way to minimize the number of defective products that cause the process to be unable to continue so that it can harm the company (Widiwati et al., 2025; Roberts et al., 2023; Tampubolon & Purba, 2021; Psarommatis et al., 2022).

PT WW is one of the companies engaged in the furniture industry using teak wood as the basic material and is one of the largest furniture exporters in the Kediri Regency area. Based on the results of observations and interviews, it is known that at PT WW there are two production areas, namely Mill 1 and Mill 2 for furniture production. From the two production floors, it is known that Mill 1 has many product defects. This happens because Mill 1 is one of the production processes that is responsible for the initial process of making furniture such as the splitting process, cutting process, drying process, forming process, and polishing process (Schlegel, 2023; Kohser et al., 2024; Donkoh, 2021).

In this study, the product analyzed is the SP-15 chair, this is because the product is the most widely sold product on the market, of course this is directly proportional to the amount of production and the number of defects that occur in the production process. However, at PT WW, the number of defects in the SP-15 chair product is currently quite high, which is 15.2%, while the standard set by the company for maximum defects is 5%, with three types of defects identified, namely broken, rotten eyes on wood, and wrong process. So that with this research, quality can be improved and the main cause of the defect can be found and a repair solution is needed that can overcome the existing problems.

To find out the root cause of defects in the SP-15 chair product at PT WW, an appropriate method is needed to reduce the level of defects in the product, namely the Fault Tree Analysis method. According to Safrudin & Rahman (2021) the Fault Tree Analysis (FTA) method is a method used to find factors that can cause failure and identify risks. FTA begins with the assumption of failure from the top event, and is detailed into basic failures, using logic gates to show the relationship between top events and basic events, both describing single conditions and a collection of various conditions that trigger failure (Sonawane et al., 2023; Ugurlu & Cicek, 2022).

If the top event and basic event of the cause of the defect are known, then the RCA method is needed to find out the most basic cause of the defect (Pazhayattil & Sharma, 2025; Papageorgiou et al., 2022; Mohd & Yusoff, 2023). According to Sidikiyah (2023) the Root Cause Analysis (RCA) method is applied to identify and fix the root cause of the problem which aims to create and implement solutions that can prevent recurring problems. The RCA method is useful for analyzing a particular failure about what happened, how it happened and why it happened (Rafsyan Zani & Supriyanto, 2021; Jena, 2024; Peters & Eng, 2021).

By combining the two methods, namely the Fault Tree Analysis (FTA) method which is used to find out the main factors causing defects in the SP-15 chair components and Root Cause Analysis (RCA) is used to systematically identify the causes of defects and help identify the main factors that must be fixed to improve the quality of the SP-15 chair product at PT WW. This study aims to determine the defects of SP-15 chair products using the Fault Tree Analysis (FTA) method and provide suggestions for improvement to reduce defects in SP-15 chair products at PT WW. In this case, it is expected that PT WW can implement this method in its production process so that the products produced are more consistent and meet the quality standards set by the company.

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Quality Control

Quality is a description of a product's properties, whose features can indicate its ability to meet needs. Therefore, there must be a match between the company's desires and the consumer's desires to create a product that leaves a unique impression on consumers. Quality functions as a competitive force and functions as security for customers (users) (Krisnaningsih et al., 2021). If you precede this quality of use with technical success indicators and that, to eliminate product variability, quality will generate further benefits (Pratika, 2023).

According to (Supriyadi, 2021) Quality control is one of the techniques needed from before the production process runs until the production process ends which has produced the final product. This quality control is carried out to produce products in the form of goods or services that are in accordance with the agreed quality standards, and will improve the quality of the product if it is not yet in accordance with the established standards, and continue to maintain the quality of the product according to the standards.

Defect Product

A defective product is a defect that reduces or damages the value or quality of the finished product. The finished product usually does not meet the specified standards but can be repaired at additional cost. This usually results in costs to the manufacturer that exceed the retail value of the product. Management of defective products for determining selling prices includes the cost of repairing defective products, including raw materials, labor, and overhead. The cost of repair depends on the cause of the product defect, namely: defective products are Normal and defective products occur due to errors.

Fault Tree Analysis (FTA)

One method that can be used to find the root cause of a problem is Fault Tree Analysis (FTA) is a technique for classifying the relationship of system component conditions leading to a particular failure mode. FTA is easier to understand because it represents the relationship between failure modes graphically (Safrudin & Rahman, 2021). Fault tree analysis is a method that provides an overview of the causal relationship between one incident and another, allowing the root cause of the problem to be found using a tree diagram (Nurfatha & Herwanto, 2023).

Starting from the fault tree analysis (FTA) diagram, the evaluation is carried out by determining the intersection method and minimum intersection. The cut-set method is a method used to determine a list of disturbance events that occur after a peak event (Putri & Ngatilah, 2021). On the other hand, the Minimum Cut Set is a list of minimum conditions that are sufficient and necessary for a peak event. The minimum cut off limit is a series of system components that can cause system failure.

Root Cause Analysis (RCA)

Root Cause Analysis (RCA) is a method used to identify and analyze a failure/defect in a system and provide improvements to the problems that occur. In addition, RCA is a process used to solve problems by identifying a problem, either a concern or a non-conformity of the problem found (Widhianingsih & Wahyuni, 2024; Haikal et al., 2025; Kaleem et al., 2024). The main objectives of root cause analysis are: preventing recurrence of problems, improving quality, improving efficiency, improving customer satisfaction (Yusuf et al., 2024; Ma et al., 2021; Soldani & Brogi, 2022; Chen et al., 2024; Adekunle et al., 2023).

5-Why Analysis is a root cause analysis (RCA) method used to analyze the factors and causes of defects in the production process. This method makes it easy to determine the root cause of a problem by asking five questions. Here are the steps.

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Methods

In this study, it is necessary to identify the variables used in the study. There are two variables, namely the dependent variable used in this study, namely the improvement of the quality of SP-15 stool products at PT WW. The independent variables used are data on the amount of production, data on the number of defects in SP-15 chair products for the period March 2024 to February 2025, and data on the types of defects including rupture defects, rotten wood defects, and wong process defects. Data collection in this study was carried out through the interview method by exchanging questions and answers directly with the company to obtain valid information regarding the quality control of SP-15 products. The observation method was carried out through direct observation at PT WW with a focus on the Plant 1 production room. Fault tree analysis (FTA) and root cause analysis (RCA) methods were used for data processing in this study.

In this study, the fault tree analysis method is used to process data, the steps are as follows: determining the main event and root cause (basic event) with a cause and effect diagram, creating a fault tree from the main event to the lower event (such as an FTA diagram), calculating the probability of each root cause event (basic event), determining the defect structure (Cut Set method), calculating the probability of defects in the FTA diagram.

The Root Cause Analysis (RCA) method is a stage used for improvement recommendations. The data processing technique using the Root Cause Analysis (RCA) method is as follows: analyze the causes of defects using the RCA method, with the technique used, namely 5 Whys to find out the cause of the problem by asking "Why" repeatedly. To find out the cause of product defects from the top to the bottom, namely the RCA method using the 5 whys analysis technique, to help explain the cause and effect relationships that occur and prevent improvements made on the surface of the problem only, and provide appropriate improvement suggestions to address the root cause of the problem to prevent the same problem from recurring. The 5 whys analysis in this study was used to identify the most basic causes of the most dominant types of defects, then suggestions for improvements will be provided to reduce defects in the Kurdi SP-15 product at PT WW.

Results and Discussion

Data collection in this study was conducted through observation and interviews with the quality control (QC) department at PT WW. The data used for data collection includes production quantity data, defect type data and number of defects per month.

Table 1. Data on the number of defects based on the type of defect in SP-15 type chair products for the period March 2024 to February 2025

Month	Good Product (pcs)	Number of Defects (per pcs) and Type of Defects			Amount
		Rupture	Rotten Eyes in Wood	Wong Process	
March	1762	112	88	80	280
April	2202	202	155	62	419
May	1568	136	109	53	298
June	2628	194	221	66	481
July	2262	169	133	40	342
August	2034	211	187	58	456
September	2765	221	174	67	462
October	4241	365	316	102	783
November	4763	340	357	109	806
December	4103	340	318	96	754

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January	3209	287	244	57	588
February	1820	149	128	45	322
Total	33357	2726	2430	835	5991

Identification of Defects

Table 1. Percentage of SP-15 Chair Product Defects for the Period March 2024 to February 2025

Type	Number of Defects	Percentage of Number of Defects (%)	Cumulative Defects Percentage (%)
Rupture	2726	45,5%	45,5%
Rotten Eyes in Wood	2430	40,6%	86,1%
Wong Process	835	13,9%	100%
Total	5991	100%	

From the table above, it is known that the rupture defects is the highest defect with a percentage value of 45.5%, then the rotten eye defect in wood with a percentage value of 40.6%, and the wrong process defect with a percentage value of 13.9%. Then the results are described with the histogram and Pareto diagram below.

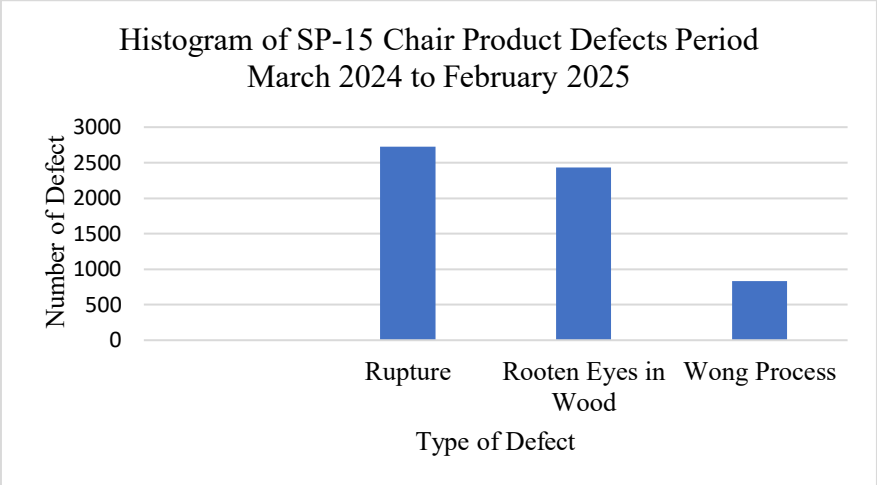

Figure 1. Histogram of Number of Defective Products from March 2024 to February 2025

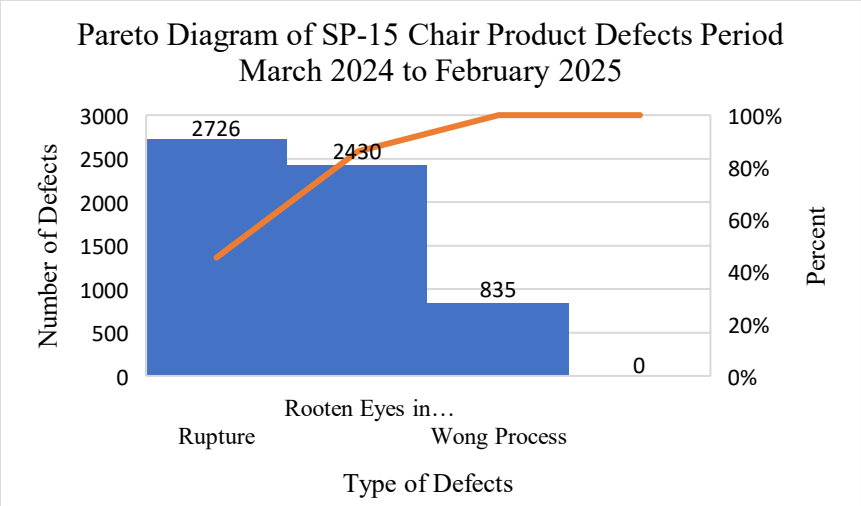

Figure 1. Diagram Pareto

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From the results of the percentage of defects and cumulative percentages in table 2 depicted in the Pareto diagram in Figure 2, it can be concluded that the SP-15 chair product has a total of 5991 defects with each defect having a different number, namely, 2726 rupture defects, 2430 rotten eye defects in wood, and 835 wong process defects. From the results of the analysis, it is known that rupture defects are defects that must be prioritized to be reduced, if this defect is successfully reduced, it will affect other causes.

Identifying the Cause of Top Events

Based on the table of defect percentages in the SP-15 chair product above, the main events can be identified with cumulative percentage results from highest to lowest, namely rupture defects, rotten wood defects, and wong process defects. Based on peak events, the cause of the defect is determined using a fishbone diagram or cause and effect diagram.

Identify the Causes of Top Event Rupture Defects

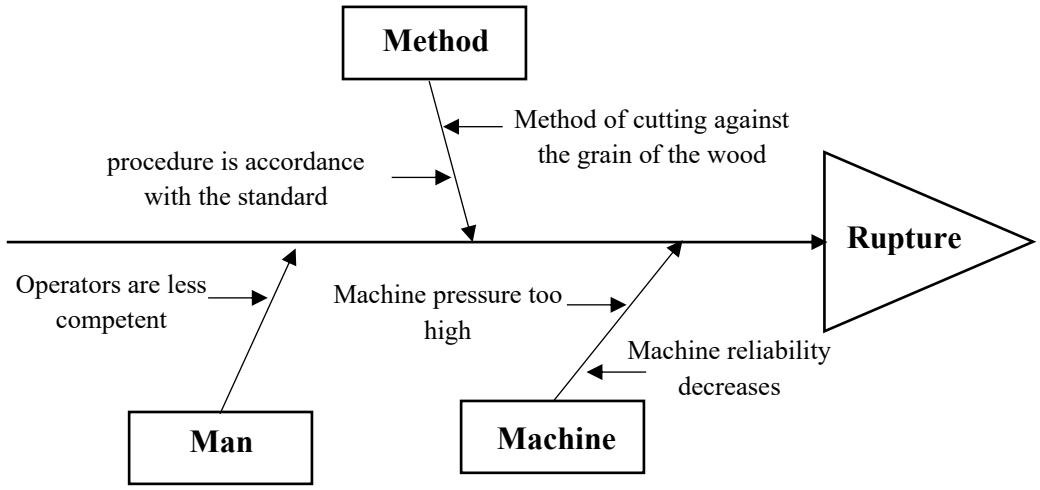

Figure 2. Fishbone diagram rapture defects

From the fishbone diagram above, it is known that the rupture defects (top event) is caused by humans with the root cause (basic event) being cutting method in against the grain, procedure is accordance with the standard, as well as operator incompetent. And caused by the machine (top event) with the root cause (basic event) being machine pressure too high and machine reliability decreases.

Identify the Causes of Top Event Rotten Eyes in Wood

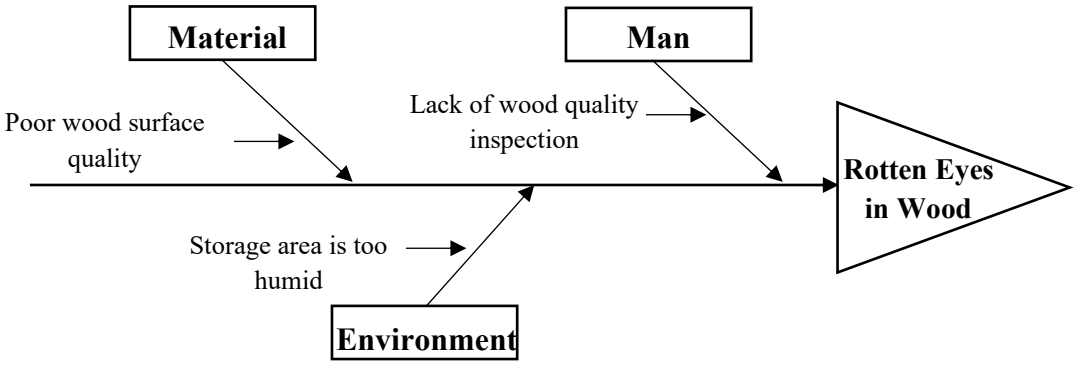

Figure 3. Fishbone diagram rotten eyes in wood

From the fishbone diagram above, it can be seen that the eye rot defect in wood (peak event) is caused by humans, while the root cause (basic event) is the lack of wood quality control. So, the cause lies in the material, with the root cause (basic event) being the poor quality of

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the wood surface. And the environment (peak event), where the real cause (basic event) is the storage space that is too humid.

Identify the Causes of Top Event Wong Process

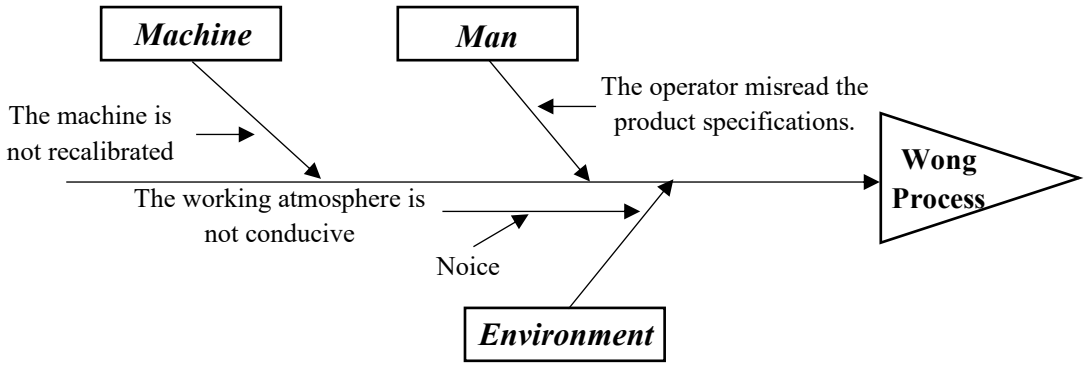

Figure 4. Fishbone diagram wong process defects

From the fishbone diagram above, it can be seen that the process defect (peak event) is caused by humans and the root cause (basic event) is the operator misread the product specifications. Then it is caused by the machine (peak event), while the root cause (basic event) is that the machine is not recalibrated. And caused by the environment (peak event), with the root cause (basic event) The working atmosphere is not conducive (Noise).

Identification of Basic Events and Calculation of the Probability of Basic Events

After the cause of the top event or top event in the type of product defect is known, the next step is to identify the root cause or basic event so that the same incident does not happen again. Therefore, observations and interviews were carried out with the QC to find out more about the basic events that occurred in the production process of the SP-15 Chair. The results showed that there were 11 types of basic events, namely: 1) Cutting method is against the grain: In the manufacture of SP-15 chair products, if the method used is against the grain, the natural strength of the wood will be weakened so that it is more easily broken; 2) Procedure is not inaccordance with the standard: Non-standard procedures are any form of negligence in the work steps that should be carried out according to SOP, such as cutting wood against the grain, using machines with excessive pressure, or not checking the condition of the knife and raw materials before the process. This negligence can pose a risk of damage to the material; 3) Operator incompetent: These incompetent operators can be caused by a lack of training in cutting or processing techniques during the production process, so this can increase the risk of cracks or breaks; 4) Machine pressure is too high: The condition of the machine also plays an important role in the production process, where if the pressure given by the cutting machine or press machine exceeds the specified standard, the wood will not withstand the pressure and eventually break; 5) Machine reliability decreased: Unmaintained machine conditions such as lack of lubrication, worn components, and blunt blades can cause unstable pressure or vibrations, which can increase the risk of breakage; 6) Lack of Wood Quality Inspection: The lack of detailed inspection processes for wood quality means that low-quality wood can pass through to the production stage, which will certainly affect the final product produced; 7) Poor Wood Surface Quality: Rot eyes can usually arise because the wood used is of low quality and does not pass the raw material inspection; 8) Storage Area is Too Humid: The raw material used for the SP-15 chair product is teak wood, if the wood is stored in an area with high humidity, it will certainly experience structural degradation, one of which is rot eyes on the wood surface; 9) Operator Misreads Product Specifications: Operators misread work instructions or product specifications, this can cause incorrect processes that will affect the product; 10) Machines Not Recalibrated: Machines that are not reset after working on different types of products can also cause process errors such as size, pressure, or quality that

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do not comply with existing provisions; 11) The Working atmosphere is not condusive: A non-conducive working environment in the production area, such as noise, can disrupt the operator's concentration, which can cause incorrect processes.

After identifying the root cause or basic event in the production process at PT WW, it was found that the incidents per day for 12 months. Working days at PT WW for 1 month are 26 days. For an example of calculating the probability of occurrence of cutting method is against the grain (P1) per day for one year with a period of March 2024 to February 2025.

Frequency of occurrence (F) of Cutting method is against the grain (P1) per day for one month, with the following formula:

$$F = \frac{f1+f2+f3+\cdots+fn}{n}$$

March

$$F = \frac{f_1+f_2+f_3+\cdots+f_{26}}{n}$$

$$= \frac{2+3+6+\cdots+5}{26}$$

$$= \frac{104}{26} = 4 \text{ per day}$$

Then, a calculation is made of the frequency of the number of errors for 12 months for the root cause of Cutting method is against the grain, followed by finding the average frequency of Cutting method is against the grain per day for one year with a period from March 2024 to February 2025. With the formula below:

• Average Frequency of Occurrence

$$= \frac{\Sigma \text{ March}+\Sigma \text{ April}+\cdots+\Sigma \text{ February}}{12}$$

$$= \frac{4+4+\cdots+4}{12}$$

$$= \frac{47}{12} = 4 \text{ pcs/month}$$

After calculating the frequency of occurrence of basic events, the results of the calculation of the average frequency of occurrence of basic events can be seen in table 1.3 below:

Table 2. Percentage of SP-15 Chair Product Defects for the Period March 2024 to February 2025

Root Causes (Basic Event)	Average Frequency of Occurance (F)
Cutting method is against the grain (P1)	4
Procedure is not in accordance with the standard (P2)	4
Operator incompetence (P3)	3
Machine pressure too high (P4)	5
Machine reliability decreases (P5)	8
Lack of wood quality inspection (P6)	4
Poor wood surface quality (P7)	5
Storage area is too humid (P8)	1
Operator misreads product specifications (P9)	4
Machine not recalibrated (P10)	3
The working atmosphere is not conducive (P11)	2

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Then continue with the calculation of total production per month, to work with the following formula:

$$T = F + S$$

March

T = F + S

T = Frequency of Occurrence + Number of Good Products

T = 4 + 1762 = 1766 pcs/month

Average production volume for Cutting method is against the grain over 12 months, namely:

$= \frac{\Sigma \text{ March} + \Sigma \text{ April} + \cdots + \Sigma \text{ February}}{12}$

$= \frac{1766 + 2206 + \cdots + 1824}{12}$

$= \frac{33404}{12} = 2784$ pcs/month

Probability of failure of cutting method is against the grain (P1) for the period March 2024 to February 2025, namely:

$= (\frac{F}{(F+S)})$

$= \left(\frac{3,9}{(2783,7)}\right)$

$= 0,0014$

And for the results of other basic event calculations, they can be seen in table 1.4 below.

Table 3. Basic Event Probability of SP-15 Chair Product Defects for the Period March 2024 to February 2025

No	Root Causes or Basic Event (P)	Average Frequency of Occurrence $(\frac{f_1 + f_2 + \cdots + f_n}{n})$	Average Total Production During 1 Year $(S + F)$	Probability of Event for 1 year $(\frac{F}{S+F})$
1	Cutting method is against the grain (P1)	4	2784	0,0014
2	Procedure is not in accordance with the standard (P2)	4	2784	0,0014
3	Operator incompetence (P3)	3	2783	0.0011
4	Machine pressure too high (P4)	5	2785	0,0017
5	Machine reliability decreases (P5)	8	2788	0,0029
6	Lack of wood quality inspection (P6)	4	2784	0,0015
7	Poor wood surface quality (P7)	5	2784	0,0016
8	Storage area is too humid (P8)	1	2781	0,0005

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No	Root Causes or Basic Event (P)	Average Frequency of Occurrence $(\frac{f_1 + f_2 + \cdots + f_n}{n}$	Average Total Production During 1 Year $(S + F)$	Probability of Event for 1 year $(\frac{F}{S+F})$
9	Operator misreads product specifications (P9)	4	2784	0,0015
10	Machine not recalibrated (P10)	3	2783	0,0011
11	The working atmosphere is not conducive (P11)	2	2782	0,0008

Fault Tree Analysis (FTA)

Starting from the fault tree analysis diagram, the evaluation is continued using the cut-set method until more specific defects are identified.

Fault Tree Analysis (FTA) Rupture Defects

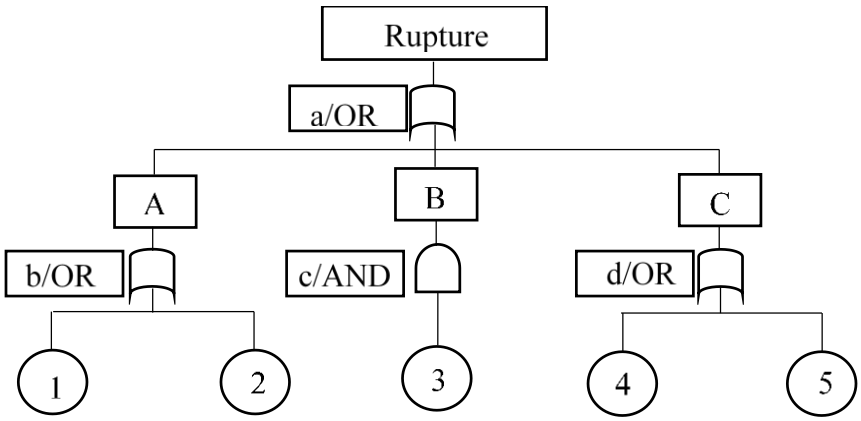

Figure 5. Fault Tree Analysis (FTA) Diagram Rupture Defect

Information:

A : Method

B : Man

C : Machine

1 : Cutting method is against the grain

2 : Procedure is not in accordance with the standard

3 : Incompetent operators

4 : Too high machine pressure

5 : Decreasing machine demand

The main causes of the occurrence of rupture defects are caused by the method, man and machine. For the method because the cutting method is against the grain, and the procedure is not in accordance with the standard. Then man because the incompetent operators. While for the machine because the too high machine pressure and the decreasing machine demand.

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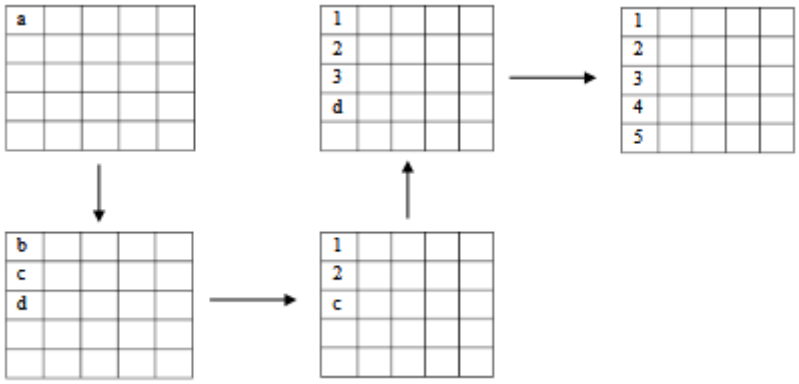

Figure 6. Cut Set Matrix and Minimal Cut Set Defect Rupture

Based on the image above, it is known that the process error defect is seen from the OR gate with the letter symbol (a) which will be directly connected to the cause, namely the Method event (b) which is described through the OR gate with the basic cause, namely the cutting method against the grain (1), and the procedure is not in accordance with the standard (2) so that in the cut set matrix it is described vertically because the causes occur differently where one of them occurs first. Then for the man event (c) it is described through the AND gate so that in the cut set matrix it is described horizontally because the basic cause is the operator is less competent (3). And for the machine event (d) which is described through the OR gate with the basic cause, namely the machine pressure is too high (4), and the machine reliability decreases (5) so that in the cut set matrix it is described vertically because the causes occur differently where one of them occurs first.

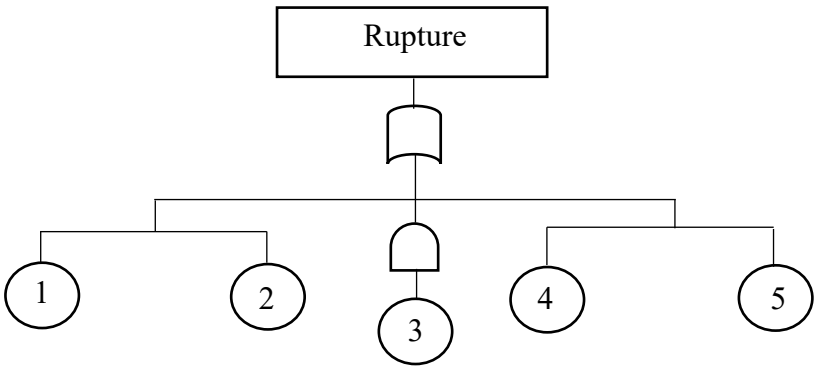

Figure 7. Equivalent Fault Tree Rupture Defect

The results of the previous minimal cut set will be re-depicted through a simplified fault tree diagram so that it can be called an equivalent fault tree which can be seen in the image below. This is done to clearly know the results of the previous fault tree diagram evaluation. In the equivalent fault tree for root cause 1, cause 2 forms an OR gate. Cause 3 forms an AND gate. For cause 4, and cause 5 form an OR gate.

For the probability results of the rupture defect caused by the basic event of the cutting method against the grain with a probability value of 0.0014, the procedure is not in accordance with the standard with a probability value of 0.0014, the incompetent operator with a probability value of 0.0011, the too high machine pressure, the probability value is 0.0017, and the decreasing machine demand, the probability value is 0.0029. Then the probability results were obtained before the evaluation, which was 0.0084 or 0.084%. While the probability results after the evaluation were 0.0085 or 0.85%. From this probability, it means that the two methods did not experience significant changes and the results obtained were optimal.

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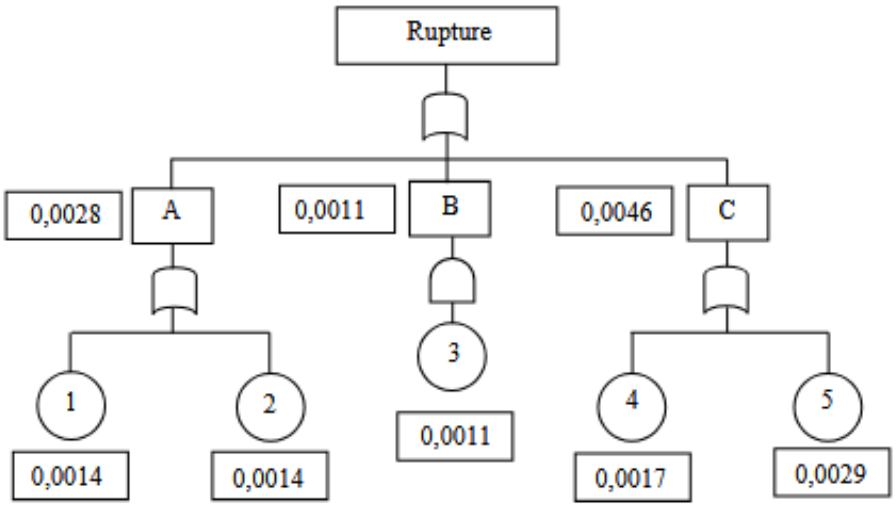

Figure 8. Probability of Defect in Rupture Defect

Fault Tree Analysis (FTA) Rotten Eyes in Wood Defects

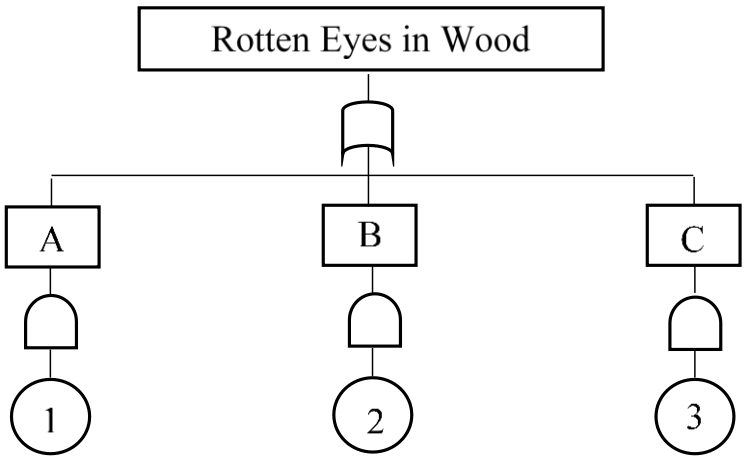

Figure 9. Fault Tree Analysis (FTA) Diagram Rotten Eyes in Wood Defect

Information:

A : Man

B : Material

C : Environment

1 : Lack of wood quality inspection

2 : Poor wood surface quality

3 : Storage area is too humid

Based on the processed data, the probability of occurrence with the most minimal defect structure is obtained. Then each defect will be identified, where the main cause of the occurrence of wood rot eye defects is caused by man, material, and environment. For man due to lack of wood quality inspection. While for material due to poor wood surface quality. And for environment because the storage area is too humid.

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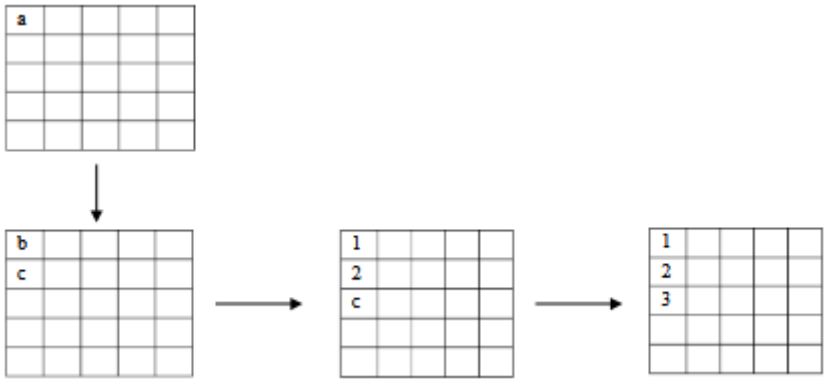

Figure 10. Cut Set Matrix and Minimal Cut Set Defect Rotten Eyes in Wood Defect

Based on the image above, it is known that the wood rot eye defect is reviewed from the OR gate with the letter symbol (a) which will be directly connected to the cause, namely the material event (b) which is depicted through the OR gate with the basic cause being the lack of wood quality inspection (1), and poor wood surface quality (2) so that in the cut set matrix it is depicted vertically because the causes occur differently where one of them occurs first. Then for the environmental event (c) which is depicted through the AND gate so that in the cut set matrix it is depicted horizontally because the basic cause is that the storage area is too humid.

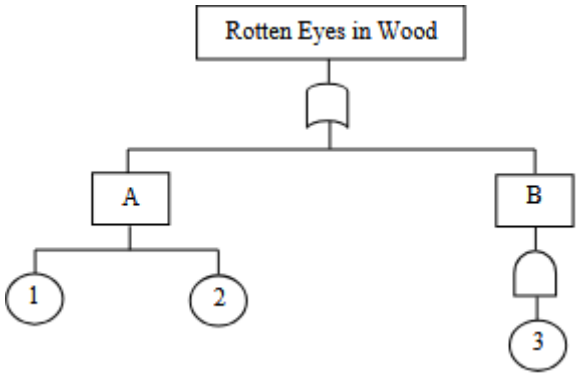

Figure 11. Equivalent Fault Tree Rotten Eyes in Wood Defect

The results of the minimal cut set will be re-described through a simplified fault tree diagram so that it can be called an equivalent fault tree which can be seen in the image below. This is done to clearly determine the results of the previous fault tree diagram evaluation. In the equivalent fault tree for root cause 1, and cause 2 form an OR gate. While for cause 3 it forms an AND gate.

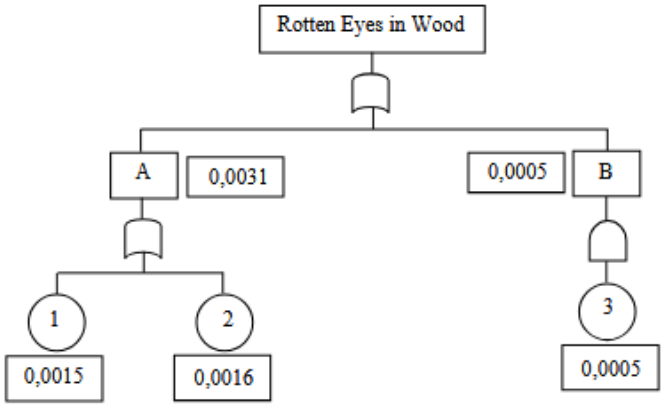

Figure 12. Probability of Defect in Rotten Eyes in Wood Defect

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For the probability results of wood rot eye defects caused by basic events lack of wood quality inspection with a probability value of 0.0015, poor wood surface quality has a probability value of 0.0016, and the storage area is too humid the probability value is 0.0005. Then the probability results before the evaluation were obtained were 0.0035 or 0.35%. While the probability results after the evaluation were 0.0036 or 0.36%. From this probability, it means that the two methods did not experience significant changes and the results obtained were optimal.

Fault Tree Analysis (FTA) Wong Process Defects

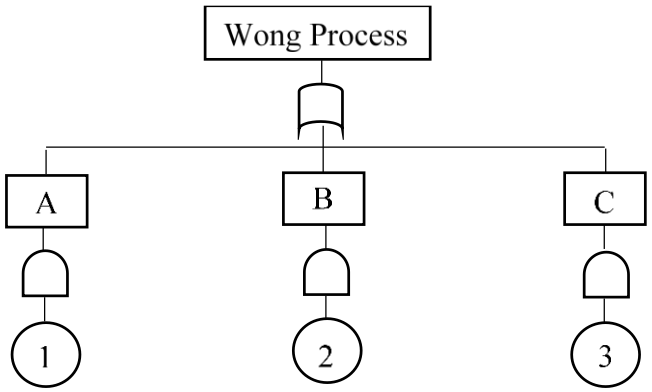

Figure 13. Fault Tree Analysis (FTA) Diagram Wong Process Defect

Information:

A : Man

B : Machine

C : Environment

1 : Operator misread the product specifications.

2 : Machine not recalibrated.

3 : The working atmosphere is not condusive (Noise)

Based on the processed data, the probability of occurrence with the most minimal defect structure is obtained. Then each defect will be identified, where the main cause of the wrong process defect is caused by man, machine, and environment. For man, it is because the operator misread the product specifications. While for the machine, it is because the machine is not recalibrated. And for the environment, it is because the working atmosphere is not conducive.

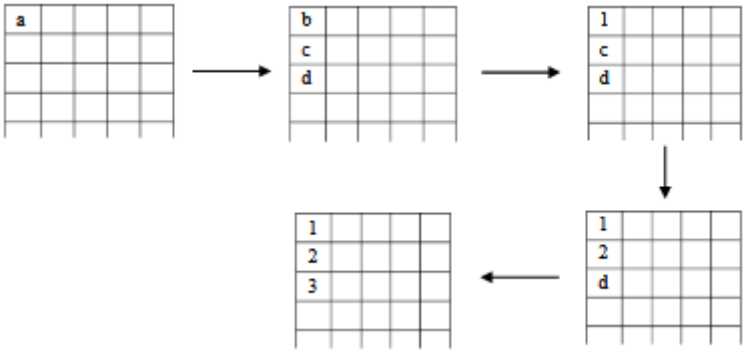

Figure 14. Cut Set Matrix and Minimal Cut Set Defect Wong Process Defect

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Based on the image above, it is known that the wood rot eye defect is reviewed from the OR gate with the letter symbol (a) which will be directly connected to the cause, namely material (b), and environment (c), therefore in the cut set matrix it is depicted vertically because the two causes occur differently where one of them occurs earlier. While for the material incident (b) which is depicted through the OR gate with the basic cause being the lack of wood quality inspection (1), and poor wood surface quality (2) so that in the cut set matrix it is depicted vertically because the cause occurs differently where one of them occurs earlier. Then for the environment incident (c) which is depicted through the AND gate so that in the cut set matrix it is depicted horizontally because the basic cause is that the storage area is too humid.

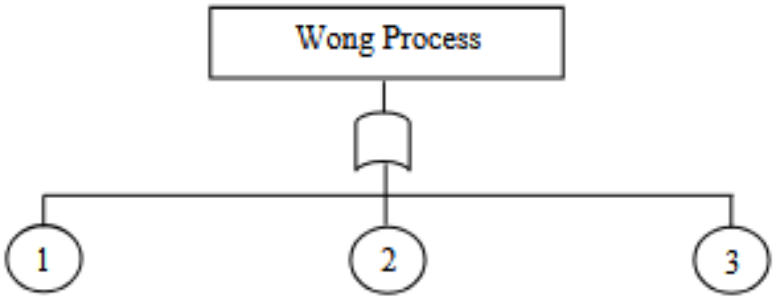

Figure 15. Equivalent Fault Tree Wong Process Defect

The result of the minimal cut set will be re-depicted through a simplified fault tree diagram so that it can be called an equivalent fault tree which can be seen in the image below. This is done to clearly know the results of the previous fault tree diagram evaluation. In the equivalent fault tree for root cause 1, and cause 2 form an OR gate. While for cause 3 it forms an AND gate.

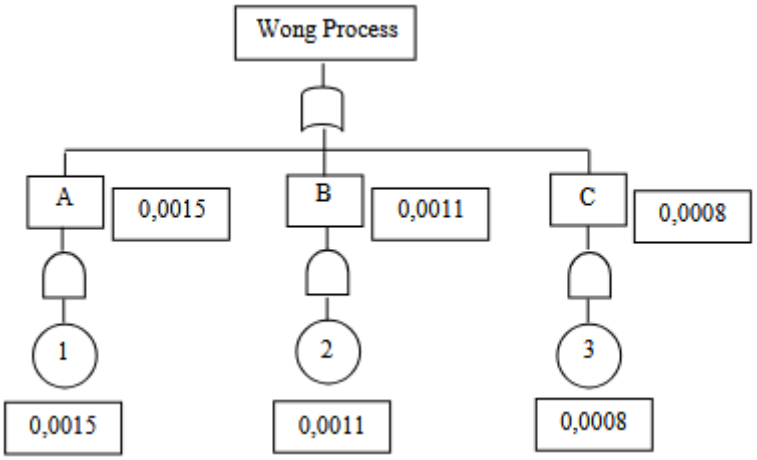

Figure 16. Probability of Defect in Wong Process Defect

For the probability results of wong process caused by the basic event of the operator misreading the product specifications with a probability value of 0.0015, the machine is not recalibrated, the probability value is 0.0011, and the working atmosphere is not conducive, the probability value is 0.0008. Then the probability results before the evaluation were obtained were 0.0033 or 0.33%. While the probability results after the evaluation were 0.0034 or 0.34%. From this probability, it means that the two methods did not experience significant changes and the results obtained were optimal.

Root Cause Analysis (RCA)

After the root cause (fundamental event) is known using fault tree analysis (FTA), the next step is to identify improvements for the type of error with the highest probability value. The probability values for the three types of defects are: rupture defect of 0.85%, rotten eyes of

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wood of 0.36%, and wong process defect of 0.34%. From the probability results, it is known that the fracture defect has the highest probability value, so it is necessary to propose improvements to improve the quality of the SP-15 chair product.

After identifying the most common types of defects, the root cause of the fracture defect is determined using the 5-Why analysis, which is shown in the table below.

Table 4. 5-Why Defect Analysis Rupture

Category	Why 1	Why 2	Why 3	Why 4	Why 5
Method	There is a crack or break in the wood when it is cut	Method of cutting against the grain of the wood	Operators do not understand the appropriate direction of wood grain	There is no technical SOP for the initial wood processing procedures	SOP is not yet available
	There is a crack or break in the wood when it is cut	Work procedures are not up to standard	There are no standard guidelines	Operators only learn from seniors and training has not been provided	The company has not established standard procedures
Man	Operator made a wrong cut	Operators are less competent	There is no structured training program	Management has not prioritized training	Lack of technical training for operators
Machine	Wood cracks or splits after cutting	Engine pressure is too high	The machine is not reset according to the type of wood	Operator does not know the appropriate settings	There is no standard pressure setting
	The cut results are unstable	Engine reliability decreases	The machine is not working optimally	Machine components wear out	Machine operation not according to procedure

After conducting a 5-why analysis in the table above, each root cause is known, therefore it is necessary to propose improvements to improve the quality of the SP-15 chair product as follows: 1) Compiling and implementing SOPs related to wood processing and installing visual guides in the work area; 2) Compiling standard work procedures and providing short training to all operators; 3) Organizing routine technical training and operator competency tests; 4) Compiling a machine pressure setting guide according to the type of wood and training operators to set it.

Attaching visual guides (infographics or diagrams) near the machine, so that they know the correct steps to operate the machine.

Conclusion

In PT WW there are 3 types of defects, namely broken defects, rotten eye defects in wood, and incorrect process defects. With 11 factors causing failure in the SP-15 Chair production process. In this case, the most dominant defect was broken defects as many as 2726, with the causal factors being method factors including cutting methods against the grain of the wood, procedures that are not in accordance with standards, human factors including incompetent operators, machine factors including too high machine pressure, decreased machine

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reliability. Then identification was carried out using fault tree analysis, the probability results before evaluation were 0.0084 or 0.84% and after evaluation were 0.085 or 0.85%. Then further identification was carried out with root cause analysis using 5 why analysis. And the suggestions for improvement given are to compile and implement SOPs related to wood processing and install visual guides in the work area, compile standard work procedures and provide short training to all operators, conduct routine technical training and operator competency tests, compile machine pressure setting guidelines according to wood type and train operators to set them, set a maintenance schedule and attach a visual guide (infographic or diagram) near the machine, so that they know the correct steps for operating the machine.

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