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ANALYSIS OF QUALITY CONTROL OF PE PLASTIC TARPAULIN PRODUCTS WITH THE FAULT TREE ANALYSIS (FTA) METHOD AT PT XYZ

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Abstract

Companies that are able to implement good quality control will be able to generate greater profits. PT Limmas Anugrah Plasindo is a manufacturing company that produces PE Plastic Tarpaulin. This company is faced with quality control problems where defective products drom production exceed company standards. So, from the problems that occurs, it is necessary to identify the defects and the causes of defects in PE Plastic Tarpaulin products and provide recommendations for improvements that must be made in tackling the problem of defects in PE Plastic Tarpaulin products defects. In identifying the causes of each defect problem can be done with the Fault Tree Analysis (FTA) is a technique used to identify risks that contribute to the occurrence of failure. From the research conducted, 4 types of defects were obtained, namely stretch woven, uneven color, folded laminate, and holes due to other objects. Of the four defects, there are 15 root causes that cause defects to occur. The highest defect was the stretch woven defects of 107.52 tons, the uneven color defect of 51.36 tons, the folded lamination defect is 35.51 tons, and the hole defect due to other objects is 28.61 tons. To achieve a significant reduction in the defect rate, improvements should be focused on defect types with the highest likelihood of occurrence, beginning with stretch woven, then uneven color, followed by folded laminate. By resolving the three most common defects, the company can lower the likelihood of product defects by 87.17%.

Keywords: Quality Control Products, Fault Tree Analysis (FTA), Tarpaulin

INTRODUCTION

In the current era of globalization, the level of competition in the industrial world is increasing very rapidly (Imamov and Semenikhina 2021). Thus, manufacturing and service industries will strive to ensure that the output or products produced are of good quality. Companies that are able to implement quality control well will be able to generate greater profits because the products produced are good so that there is minimal damage (Javaid et al. 2021). To produce quality products or services, a series of processes are needed that require various resources, including labor, time, money, technology, and others (Foster and Gardner 2022). All of these necessary resources need to be managed properly and correctly so that they can be utilized effectively and efficiently to obtain optimal results through quality control (Mizuno 2020).

PT Limmas Anugrah Plasindo is a manufacturing company that produces PE plastic tarpaulin rollers. This type of tarpaulin is the most and easiest to find on the market because of its waterproof use and the price offered is very affordable. PT Limmas Anugrah Plasindo is faced with quite a challenge, where consumers increasingly want the quality of the products produced by the company. The output of PE plastic tarpaulin production at PT Limmas Anugrah Plasindo has several defective products that exceed company standards. So, this can be detrimental to the company because the PE plastic tarpaulin produced becomes defective. The standard set by the company in controlling the quality of PE plastic tarpaulin is 5% of production. However, the current average defect rate is 6.13%. Quality control in the manufacturing industry is an important element to ensure that the products produced meet the set standards. So, from the problems that occur, it is necessary to identify the causes of defects in PE plastic tarpaulin products and provide recommendations for improvement plans to tackle the problem of PE plastic tarpaulin product defects.

From the above problems, it can be seen that PE plastic tarpaulin product defects at PT Limmas Anugrah Plasindo exceed the standards set by the company. Thus, it is necessary to control quality control by identifying the causes of each defect problem with various approaches and methods, one of which is the Fault Tree Analysis (FTA) method. Fault Tree Analysis is a systematic, deductive method used to analyze the potential causes of system failures (Öztürk et al. 2023). The Fault Tree Analysis (FTA) identifies and solves problems

by studying the affected areas. Fault Tree Analysis can identify failures in a system and detail the causes of peak failures to basic failures presented with a visual display (Chen et al. 2023). So, the identification results can be rooted like a tree. Fault Tree Analysis also allows a team to think about and organize the sequence or pattern of errors that must occur to find out errors at a specific level (Yazdi et al. 2023). The output of this Fault Tree Analysis method is to determine the root causes of problems that cause product defects (Ikwan, Sanders, and Hassan 2021). This study aims to identify the types of defects that frequently occur and to determine their causes so that recommendations can be made to minimize them in the future.

REVIEW OF LITERATURE

The Fault Tree Analysis (FTA) method is a technique used to identify risks that contribute to failure. This method is carried out with a top-down approach, which begins with the assumption of failure from the top event and then details the causes of a top event to a basic failure (root cause) (Bujna et al. 2023; Wulandari, Hakim, and Haris 2022). A Fault Tree illustrates the state of system components (basic events) and the relationship between basic events and top events states the connection in logic gates (Aslansefat et al. 2020). A fault tree is a graphical model that involves various parallels and combinations of examples of errors that will result in the occurrence of previously defined undesirable events or can also be interpreted as a picture of the logical reciprocal relationship of basic events that lead to undesirable events becoming the peak event of the fault tree (Muchsinin and Sulistiyowati 2022; Ehiagwina et al. 2022).

According to (Signoret et al. 2021), a fault Tree Analysis (FTA) is generally carried out through 5 steps. These steps are: 1) Identify the main events to be analyzed and find out the cause of the event, so that from the observation of this data it will be possible to identify unwanted events; 2) Draw a graphical model of the Fault Tree; 3) Finding the minimum Cut Set of the Fault Tree analysis; 4) Perform qualitative analysis of the Fault Tree; 5) Perform quantitative analysis of the Fault Tree.

RESEARCH METHOD

The method used in this study is quantitative research. The first stage carried out in this study is a literature review to obtain a theoretical basis used in the study. The next stage is a preliminary study to determine the problems that occur at the research location. After the preliminary stage, the next step is to determine the research objectives and identify variables. Data collection can be done through interviews with the Quality Control of PT XYZ to determine the causes of the types of defects that occur in the PE plastic tarpaulin produced and document studies to obtain production data. This research began in February 2023 and continued until the data needed for this study was complete.

Data processing and analysis techniques were carried out using the Fault Tree Analysis (FTA) method. The Fault Tree Analysis (FTA) method is a top-down approach that begins with assuming errors or failures of an event and then delves deeper to reach the basic failures (Rochmoeljati and Nugraha 2023). The analysis in this study produces recommendations for improvements to overcome quality control problems in PE plastic tarpaulin product defects.

The first step is to identify the top event, which is the unwanted occurrence or failure that is the main focus of the analysis (Markulik et al. 2021). This is the critical event that you want to prevent or understand its causes. Create a fault tree diagram starting from the top event. This diagram will display various events or conditions (referred to as basic events) that can trigger the top event. Each basic event is connected to the top event using logic gates such as AND, OR, and others to show the cause-and-effect relationships between these events. Utilize logic gates to understand how combinations of various basic events can lead to the top event (Häring and Häring 2021). For example, an AND gate indicates that all related events must occur for the top event to occur, while an OR gate indicates that only one of the events needs to occur to trigger the top event. Next, trace and elaborate on the basic events until you find the most fundamental root causes. These root causes are specific events that, if eliminated or controlled, can prevent the occurrence of the top event. If necessary, perform a quantitative analysis to determine the likelihood of the top event occurring based on the probabilities of each basic event, which may involve mathematical and statistical calculations (Masalegooyan, Piadeh, and Behzadian 2022). Based on the analysis results,

develop recommendations for preventive or mitigation actions to reduce the risk of the top event occurring (Sakar et al. 2021). These recommendations might include design improvements, additional safety measures, or changes to operational procedures (Budiyanto and Fernanda 2020). The final step is to review the analysis results to ensure that all potential causes have been identified and that the recommended actions are effective in preventing the top event (Wu, Liu, and Nie 2021). Validate with data or simulations if possible.

RESULTS AND DISCUSSION

In this study, the data used are data on the amount of production and data on the type and amount of PE plastic tarpaulin product defects over 12 months. The average product defect rate is 6.13%, with the details of the defects shown in Table 1. There are 4 types of defects in PE plastic tarpaulin products, namely stretchy woven defects, uneven color defects, folded lamination defects, and hole due to other objects defect.

Table 1
Total Production Data and Defect Type Data of PE Plastic Tarpaulin Products Period of January 2023 to December 2023

Month	Production Amount (Tons)	Number of Defects of Each Type (Tons)			
		Stretch Woven	Uneven Color	Folded Laminate	Holes due to Other Objects
January	251,75	8,46	5,22	2,64	1,85
February	300,12	9,25	3,95	2,74	2,17
March	275,44	8,36	3,88	2,9	2,84
April	266,42	9,14	3,74	3,27	1,70
May	355,52	9,23	5,57	3,12	2,86
Juny	310,66	9,23	3,83	3,28	2,39
July	290,86	8,21	3,82	2,92	2,10
Agustus	265,35	8,53	4,57	3,46	1,97
September	322,44	8,16	3,68	2,53	2,30
October	305,20	9,28	3,70	3,38	2,59
November	384,42	9,87	4,85	2,33	2,95
December	352,25	9,80	4,57	2,94	2,89

From the data above, further data processing is carried out into histograms and Pareto diagrams to determine the defect type with the highest percentage (most frequently occurring) as shown below.

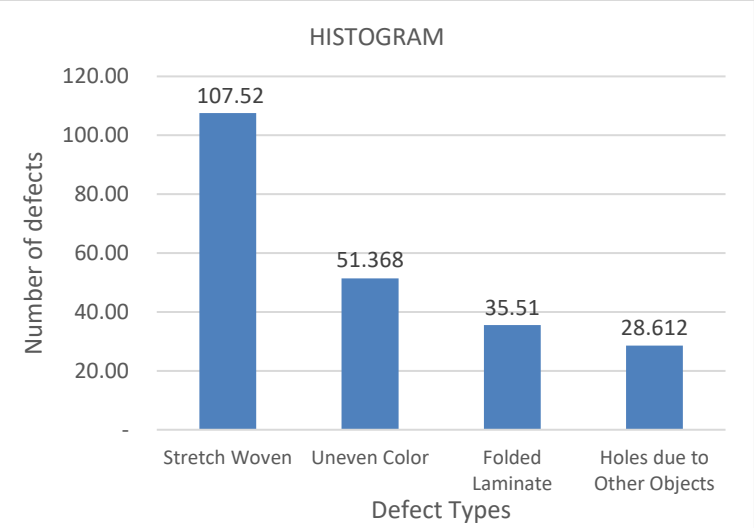

Figure 1
Histogram

Based on Figure 1, it is known that the current defect in the PE plastic tarpaulin production process is dominated by the defect of stretch woven with a total amount of 107.52 tons.

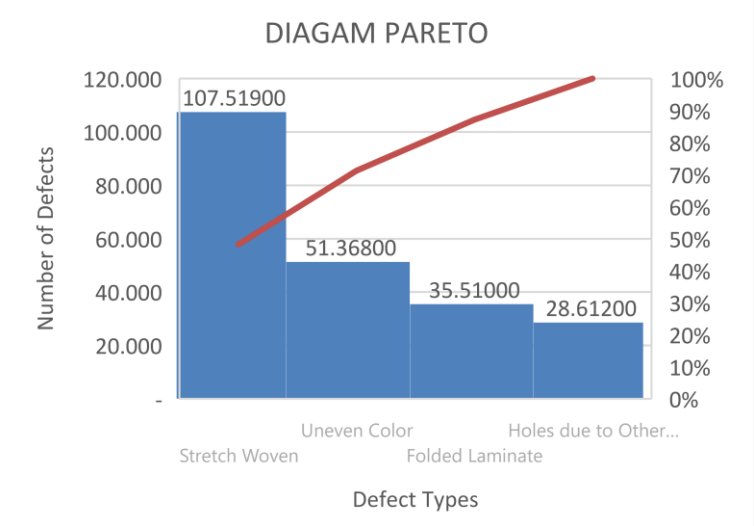

Figure 2
Pareto Diagram

Based on Figure 2, it is known that currently the product defect in the PE plastic tarpaulin production process is dominated by the defect of stretch woven with a total number of defects of 107.52 tons or 48.21%.

Fault Tree Analysis (FTA) of The Stretch Woven Defects

It can be seen in Figure 3 below which is a Fault Tree Analysis (FTA) of the stretch woven defects.

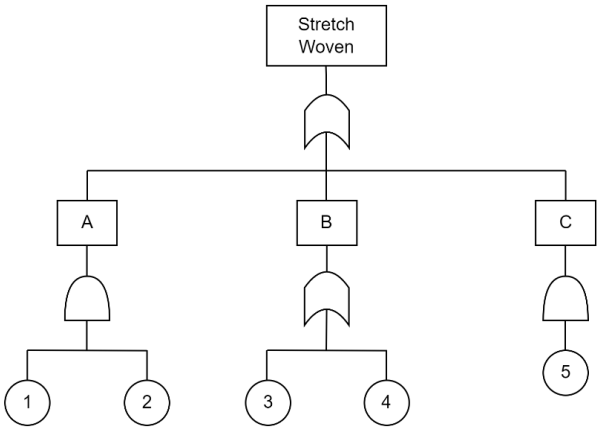

Figure 3
Fault Tree Analysis (FTA) of The Stretch Woven Defects

Information:

A : Machine Jammed
B : Human Error
C : Dark Production Room
1 : Thread Breaks off Line
2 : Shuttle Direction and Roll Pull Not Matched
3 : Incompetent Operator
4 : Wron Thread Count
5 : Insufficient Illumination

Next, a defect evaluation will be carried out by obtaining the shape of the cut set matrix of the basic causes of the stretch woven defect as shown in Figure 4 below:

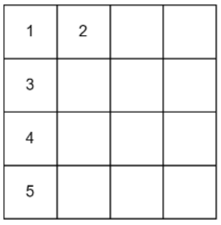

Figure 4
Cut Set Matrix of The Stretch Woven Defects

The main causes of the stretch woven defects are caused by machine jammed, human error, and dark production room. The machine jammed are caused by thread breaks off the line and shuttle direction and roll pull not matched. Human errors are caused by incompetent operator and wrong thread count. Meanwhile, the dark production room is caused by insufficient illumination.

The probability result calculated before evaluation is 0.0535 or 5.35% for 12 months of production process. While the probability calculated after the evaluation is 0.0535 or 5.35% for the 12 months of production process. This probability shows that the two methods have not changed significantly and both methods get optimal results.

Fault Tree Analysis (FTA) of The Uneven Color Defects

It can be seen in Figure 5 below which is a Fault Tree Analysis (FTA) of the uneven color defects.

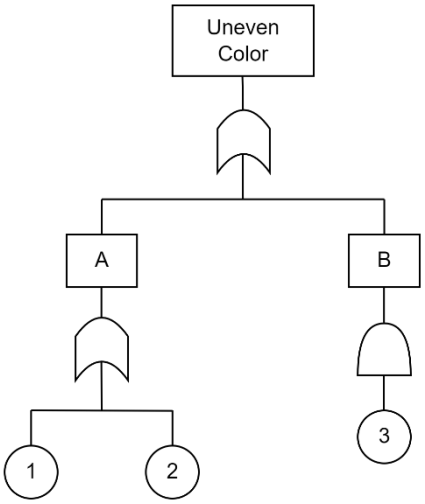

Figure 5
Fault Tree Analysis (FTA) of The Uneven Color Defects

Information:

A : Machines that needs Maintenance
B : Material
1 : Color Stirring on Machine Not Homogeneous
2 : Temperature Not Suitable
3 : Material Quality is Not Good

Next, a defect evaluation will be carried out by obtaining the shape of the cut set matrix of the basic causes of the uneven color defect as shown in Figure 6 below:

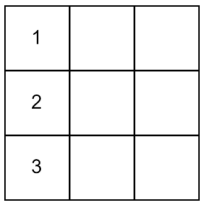

Figure 6
Cut Set Matrix of The Uneven Color Defects

The main causes of the uneven color defects are caused by machines that need maintenance and material. The machine needs maintenance are caused by color string on the machine is not homogeneous and the temperature is not suitable. Meanwhile, material is caused by material quality is not good.

The probability result calculated before evaluation is 0,0375 or 3,75% for 12 months of production process. While the probability calculated after the evaluation is 0,0376 or 3,76% for the 12-month production process. This probability shows that the two methods have not changed significantly and both methods get optimal results.

Fault Tree Analysis (FTA) of The Folded Laminate Defects

It can be seen in the Figure 7 below which is a Fault Tree Analysis (FTA) of the folded laminate defects.

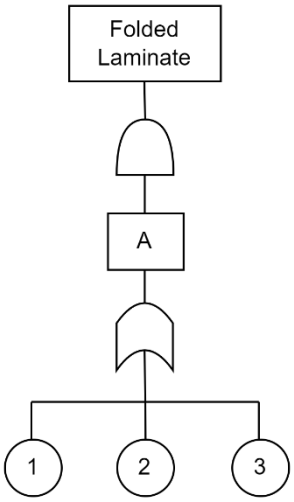

Figure 7
Fault Tree Analysis (FTA) of The Folded Laminate Defects

Information:

A : Human Error

1 : Operator Haste
2 : Operator Fatigue
3 : Improper Connection Process

Next, a defect evaluation will be carried out by obtaining the shape of the cut set matrix of the basic causes of the folded laminate defect as shown in the Figure 8 below:

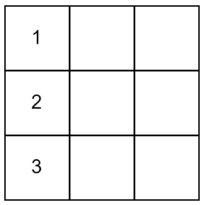

Figure 8
Cut Set Matrix of The Folded Laminate Defects

The main causes of the folded laminate defect are caused by human error. Human errors are caused by operator haste, operator fatigue, and improper connection process.

The probability result calculated before evaluation is 0,0532 or 5,32% for 12 months of production process. While the probability calculated after the evaluation is 0,0532 or 5,32% for the 12-month production process. This probability shows that the two methods have not changed significantly and both methods get optimal results.

Fault Tree Analysis (FTA) of The Holes due to Other Objects Defects

It can be seen in the Figure 8 below which is a Fault Tree Analysis (FTA) of the holes due to other objects defects.

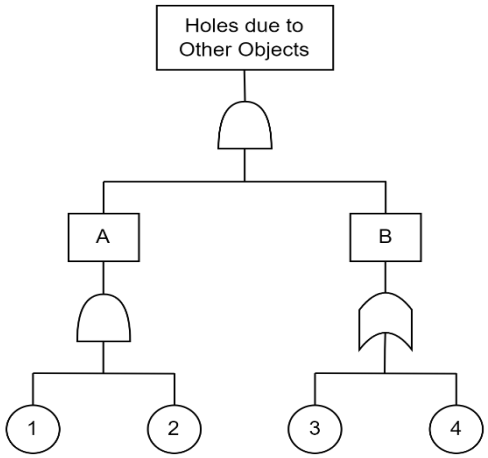

Figure 9
Fault Tree Analysis (FTA) of The Holes due to Other Objects Defects

Information:

A : Human Error
B : Hit by Production Tools/Materials
1 : Operator Negligence
2 : Product Distribution is Not Appropiate
3 : Hit by Iron on Forklift
4 : Hit by The End of The Wooden Pallet

Next, a defect evaluation will be carried out by obtaining the shape of the cut set matrix of the basic causes of the holes due to other objects' defects as shown in Figure 10 below:

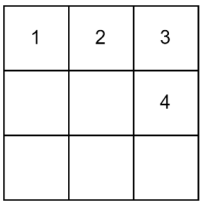

Figure 10
Cut Set Matrix of The Holes due to Other Objects Defects

The main causes of the holes due to other objects' defects are caused by human error and hit by production tools/materials. The human errors are caused by operator negligence and product distribution is not appropriate. Meanwhile, hit by production tools/materials are caused by being hit by iron on the forklift and hit by the end of the wooden pallet.

The probability result calculated before evaluation is 0,0490 or 4,90% for 12 months of the production process. While the probability calculated after the evaluation is 0,0496 or 4,96% for the 12-month production process. This probability shows that the two methods have not changed significantly and both methods get optimal results.

Improvement Recommendations

After identifying the root cause or basic event of each top event and calculating the probability value of a defect that will occur based on the top event, it will be continued by providing improvement recommendations for each root cause or basic event of a defect as in the Table 2 below.

Table 2
Improvement Recommendations

Top Event	Basic Event	Improvement Recommendations
Stretch Woven	Thread Breaks Off-Line	Enhance monitoring of the loom machine, particularly the yarn path, to ensure that any broken yarns are promptly repaired.
	Shuttle Direction and Roll Pull Not Matched	Cleaning and inspecting the loom machine so that the shuttle and roll pull are in the right direction.
	Incompetent Operator	Conduct regular training and evaluation to help improve workers' ability to operate loom machines to minimize errors.
	Wrong Thread Count	Monitoring and checking before each process on the loom machine so that there will be no missing threads during the process.
	Insufficient Illumination	Install new lights and replace dim ones to ensure adequate lighting, helping workers to focus better and work more efficiently.
Uneven Color	Color Stirring on Machine Not Homogeneous	Regularly clean and inspect the lamination and coloring machines to promptly replace any faulty spare parts.
	Temperature Not Suitable	Implement stringent temperature controls on the coloring machine to ensure it delivers consistent, high-quality color results.
	Material quality is not good	Monitoring suppliers to ensure that the raw materials received meet the specifications of PT Limmas Anugrah Plasindo.
Folded Laminate	Operator Haste	Conduct regular supervision of employees involved in the production process to ensure they remain attentive and careful in their work.
	Operator Fatigue	Increase the number of employees or lower high production targets to prevent employee exhaustion and improve the quality of production results.
	Improper connection process	Perform regular supervision of each employee's work methods, particularly focusing on those who are careless in the tarpaulin connection section, to prevent the recurrence of folded laminate defects.
Holes due to Other Objects	Operator Negligence	Conduct routine supervision of employees who work in the production process so that employees can pay more attention to the surrounding environment while working.

Top Event	Basic Event	Improvement Recommendations
	Product Distribution is Not Appropriate	Implement regular supervision of employees involved in product distribution to ensure they are cautious and attentive to machines or objects that could potentially cause defects in the products.
	Hit by Iron on Forklift	Ensure careful supervision during product transfers. Reduce the sharpness of the forklift iron by covering it with insulation or sponge to prevent perforation of the tarpaulin.
	Hit by the end of the wooden pallet	Thoroughly inspect tools that are near the product and remove any sharp items that could puncture the tarpaulin. Reduce the sharpness at the end of the pallet by adding insulation or sponge to prevent the tarp from being perforated.

To significantly reduce the defect percentage, improvements should be prioritized based on the defect types with the highest occurrence probability (Relkar 2021), starting with stretch woven, followed by uneven color, folded laminate, and finally, holes. By addressing the three most frequent defects, the company can reduce the probability of product defects by 87.17%.

CONCLUSION

There are 4 types of defects in PE plastic tarpaulin products, namely the stretch woven defects, the uneven color defects, the folded laminate defects, and the holes due to other objects' defects. There are 15 root causes of the 4 defects above that cause defects to occur. For the stretch woven defects, the number that occurred was 107.52 tons with the highest probability of root cause occurring incompetent operator at 1.62%. For the uneven color defects, the number that occurred was 51.36 tons with the highest probability of root cause occurring color stirring on the machine not homogeneous at 2.05%. For the folded laminate defects, the number that occurred was 35.51 tons with the highest probability of root cause occurring operator fatigue at 2.41%. Meanwhile, for the holes due to other objects' defects, the number that occurred was 28.61% with the highest probability of root cause occurring product distribution is not appropriate at 1.51%. By addressing the three most frequent

defects (stretch woven, uneven color, and folded laminate) the company can reduce the probability of product defects by 87.17%.

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