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Combination of FTA and FMEA methods to improve efficiency in the manufacturing company

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Abstract: Toroidal is an inductor with an O-ring core. In 2021 there was an increase in the percentage of toroidal disability, namely the highest percentage of disability at 2.78%, while in 2020 the highest percentage of disability was only 1.33%. Therefore, companies need to make improvements to the quality of their products to prevent a continuous rise in the percentage of defects over time. This study aims to propose an enhancement to reduce/prevent defects in toroidal inductor products. The method used is the Fault Tree Analysis (FTA) and Failure Mode and Effect Analysis (FMEA). The FMEA method is utilized to reduce flaws that occur by considering the value of the risk priority number (RPN). The FTA method is used to identify possible defects by applying analysis of the fault tree description. The results of this study are that improvements should be focused on the failure mode of the wound wire because it gets the highest RPN value of 216 with the cause being less focused workers, while the lowest RPN value is on the red pin failure mode of 56 with the cause of no sandpaper changing schedule. From the results of the study, several suggestions for improvements were made in the form of increasing supervision for workers, increasing rest periods, conducting training, installing display limits for stripping, repairing stripping machines, replacing vise, repairing worktables, and making a schedule for sandpaper replacement prevents the defect. Companies must make improvements to human flows and ensure tools and materials are in optimal condition.

1 Introduction

The electronics industry is one type of industry that consistently has the largest contribution to economic growth in Indonesia in 2019 [1-3]. In its development, the electronics industry has become a big consideration for business actors in the field of electronic equipment spare parts to expand their scope and contribute to its improvement. CV. CKM is a company that produces spare parts for electronic equipment. Electronic equipment produced by CV. CKM is a toroidal inductor.

This toroidal inductor itself is an electronic equipment spare part that functions as a store of energy or electric current with a larger inductance and a size that tends to be smaller than other types of inductors. The toroidal core is usually circular so that the magnetic field is closed and relatively little or even does not induct other components in the vicinity.

Along with the development of the electronics industry, in 2021 there was a surge in demand for toroidal products at CV. CKM causes the manufacturing company to produce more products than usual. The more companies produce products, it turns out that the more defective products are produced by the company. In 2021 the highest percentage of defective products produced by the company was 2.78%, this is the highest number for the percentage of defects in the company compared to previous years which was only in the range of 1%.

The existence of defective products certainly results in waste for the company, both in terms of materials and also in terms of the disposal of the defective product [4]. Although some defective products can be reworked, the presence of rework defects is also very detrimental because the company will need additional costs to reprocess the reworked defective products [5].

In addition to the losses described previously, defective products are very dangerous if they escape the quality control section and are used by the customer. Because considering its function as an inductor, if there is a mismatch such as a scratch on the wire (wire wound) it will result in an induction field or an open magnetic field so that it can induce other components that are around, and if there is a lack of stripping defects it can cause a red pin due to If the enamel wire is not peeled properly, it will result in not flowing or not optimally flowing the magnetic field by the toroidal.

Based on these problems, the company must take corrective steps to reduce or even eliminate defective toroidal inductors. So, the objectives of this study are:

a. Recognize factors causing defects in toroidal products in CV. CKM.

b. Make suggestions for improvement based on the priority of repairs to reduce defective products.

2 Literature review

This study was carried out using methods of Fault Tree Analysis (FTA) and Failure Mode and Effect Analysis (FMEA). Failure Mode and Effect Analysis (FMEA) is a procedure to describe various kinds of potential failures in a structure and then analyze them to determine their effect on the system so that they can be classified based on their severity [6]. Meanwhile, Fault Tree Analysis (FTA) is an analysis technique of failure conducted from top to down that aims to find the cause or a combination of causes that may cause unsafe conditions to a lower or basic failure rate. This makes FTAs an excellent complement to FMEA [7]. The FTA used in this study is to find out factors causing failures in the FMEA manufacturing process, namely at the phase of determining the cause of failure. FMEA is an effective and formidable analytical tool that is greatly used to check modes of failure and terminate the possibility of failure [8].

2.1 Fault Tree Analysis (FTA)

FTA or Fault Tree Analysis (FTA) is an approach applied from top to down that is used to analyze failures that start with potentially unwanted events and then determine the causes of how these events could occur [9]. FTA is also an alternative to identify the possibility of failure by using a diagram of a fault tree as reasoning that signifies the relationship between a failure and the cause of the failure [7]. This logic gate will later help in building a more detailed schema of the relationship between events that can affect its quality [10]. The logic gates that are usually used in the FTA manufacturing process consist of AND gates which are used when all input events occur and OR gates are used when one of the input events occurs [11]. The event symbols that are often used for making FTAs are the Top Event symbol which symbolizes the main event which is always placed at the peak of the tree of fault, and also the event symbol which describes an intermediate failure event that can be used anywhere except at the basic level of the fault tree and the basic event symbol which symbolizes the lowest failure event or base on the fault tree [12]. FTA differs from diagrams of a block of reliability and has a wider scope than diagrams of reliability block [13,14].

2.2 Failure Mode and Effect Analysis (FMEA)

Failure Mode and Effect Analysis (FMEA) is a structured way that can identify and prevent as many failures as possible [15-17]. The method of FMEA is used to set, recognize, and abolish failures or potential failures before the product reaches the customer [18].

FMEA has a purpose to perform any action to abolish and degrade the occurrence of failures based on activities that have the highest potential [19]. FMEA can assist in selecting critical parameters of each process [20]. In addition, FMEA can also document actions regarding the risk of failure that can be used by companies for continuous improvement. The steps taken in making FMEA documentation are [21]:

a. Determine the components of the production system or process be analyzed.
b. Identify the function of the system or production process.
c. Identify the mode of failure.
d. Determine the influence of the failures of each process.
e. Specify the cause of failure.
f. Specify value of severity.
g. Specify occurrence value.
h. Specify value of detection.
i. Calculating the Risk Priority Number (RPN) value is carried out to determine a failure that becomes a priority from each mode of failure using the following formula: RPN = S x O X N (1).
j. Recommend corrective actions of the highest priority.

FMEA is usually used to evaluate parameters such as occurrence, severity, and also detection in determining the Risk Priority Number (RPN) [22]. The severity value (S) determination or the severity value of this failure starts with a scale of 1 as the smallest scale with low consequences to a scale of 10 with the highest consequences, so that the severity scale assessment is based on how serious the effects of a failure are [23]. While the assessment of occurrence or probability level usually refers to the failure mode or several failures on a scale of 1 to 10, where 1 becomes the lowest possibility of failures, while 10 turns out to be the highest one [22]. As for the detection value based on the possibility of failure to be detected which is given a value scale of 1 to the most difficult or even undetectable with a scale of 10, the determination of this detection scale refers to the cause of the failure with the current controls [23]. FMEA method is utilized to determine which risks have the greatest concern and action is needed to prevent problems before they arise [24]. The smallest RPN value is better than the largest because the largest value indicates the severity of the risk of failure.

3 Methods

The use of FMEA and FTA methods can be merged for analysis of failures so that the advantages of each of these methods can be obtained, by using the FMEA and FTA approaches separately or by using a combined approach between the two [22]. FTA describes the causes of errors in more detail by pointing to the topmost event which is not expected to occur, while FMEA provides an overview of where this error occurs and what effects will be caused by the topmost event error [25].

Compared to the use of FTA and FMEA alone, researchers prefer to utilize a merger of FMEA and FTA because it is considered to have an advantage in detecting errors [26]. In addition, FTA is considered only able to analyze the causes of failure in detail without considering the criticality and risks that exist, so FMEA is needed as a complement to FTA because FMEA can assess criticality and risk [7]. The combination of these two methods is recommended to be used for production processes that are carried out repeatedly because it provides a clear view of analysis, collecting mechanism of similar data, and the relations between error modes and failures [26].

4 Result and discussion

Problem-solving is used using the FTA and FMEA methods. The use of FTA in this research is a complement to the process of making FMEA. At the stage of making FMEA, namely in determining factors causing failures, the FTA method is utilized to determine factors causing failure to the basic cause.

4.1 Identify Failure Mode

Before identifying the cause of failure, the initial step in building an FMEA is to identify the failure mode. recognition of modes of failure or types of defects will be described using a diagram called Pareto to specify the dominant type of flaw that causes disabilities. The Pareto diagram for each type of disability can be seen in Figure 1.

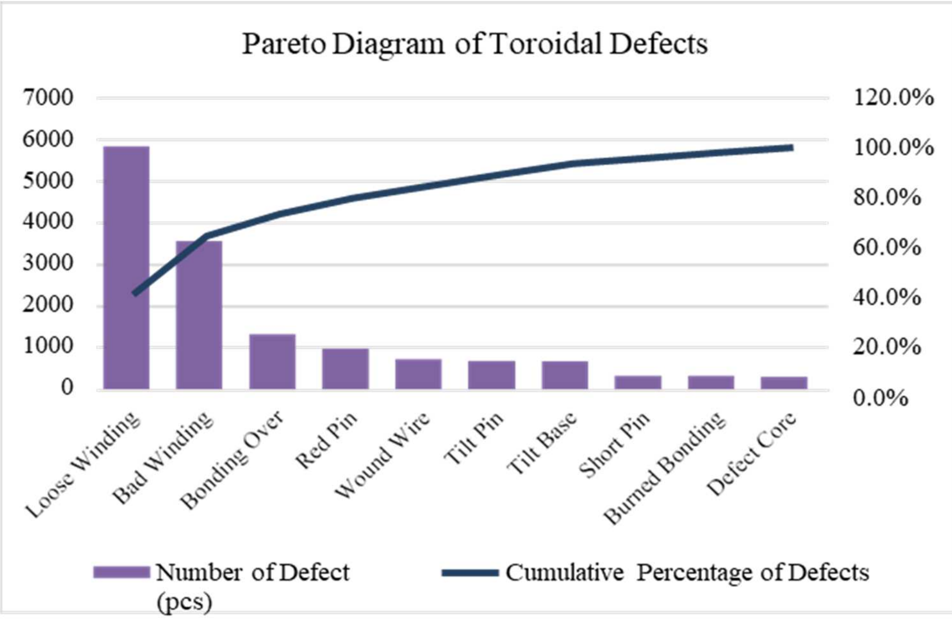

Figure 1 Pareto diagram types of Toroidal Inductor Product Defects

Under the Pareto 80:20 principle, the failure mode will then be identified as the cause of the failure, namely loose winding, bad winding, bonding over, red pins, and wound wires which are included in the 80% cumulative percentage of defects. So, these five types of defects or failure modes must be corrected so that defective products can be reduced.

4.2 Identify Causes of Failure

To build an FMEA, you must first identify the causes of failure. The failure to be analyzed further is following the dominant disability on the diagram of Pareto, namely the top five kinds of defects which are included in 80% of cumulative defects. Identification of the causes of failure exist at the phase of making this FMEA is done employing FTA. The use of FTA for the cause of this failure because FTA can describe the causes of failure based on the top events to the most basic causes that cause failure or defects. Identification of factors causing failure using the fault tree analysis is provided in Figure 2 – Figure 6.

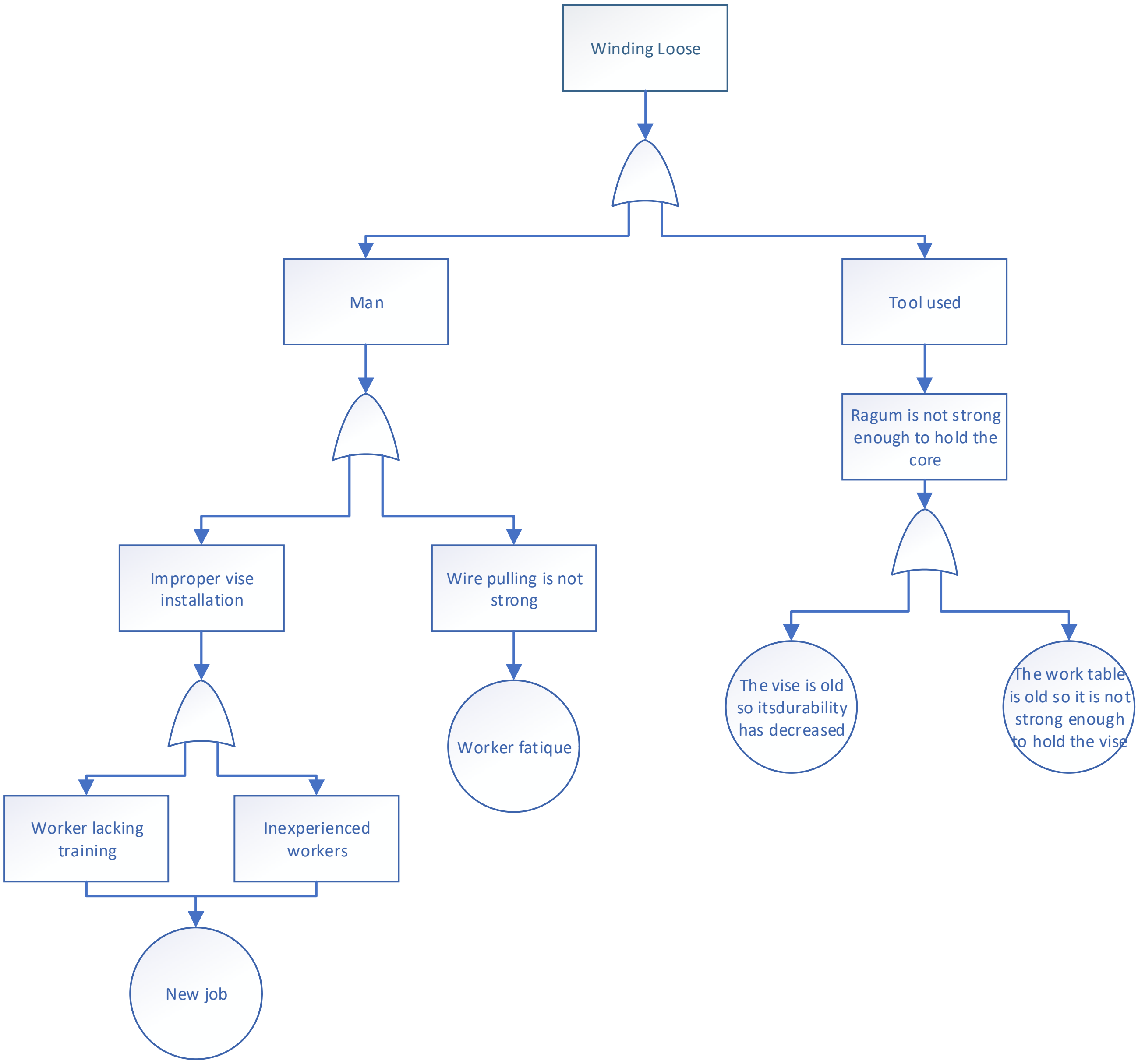

Figure 2 FTA Winding Loose

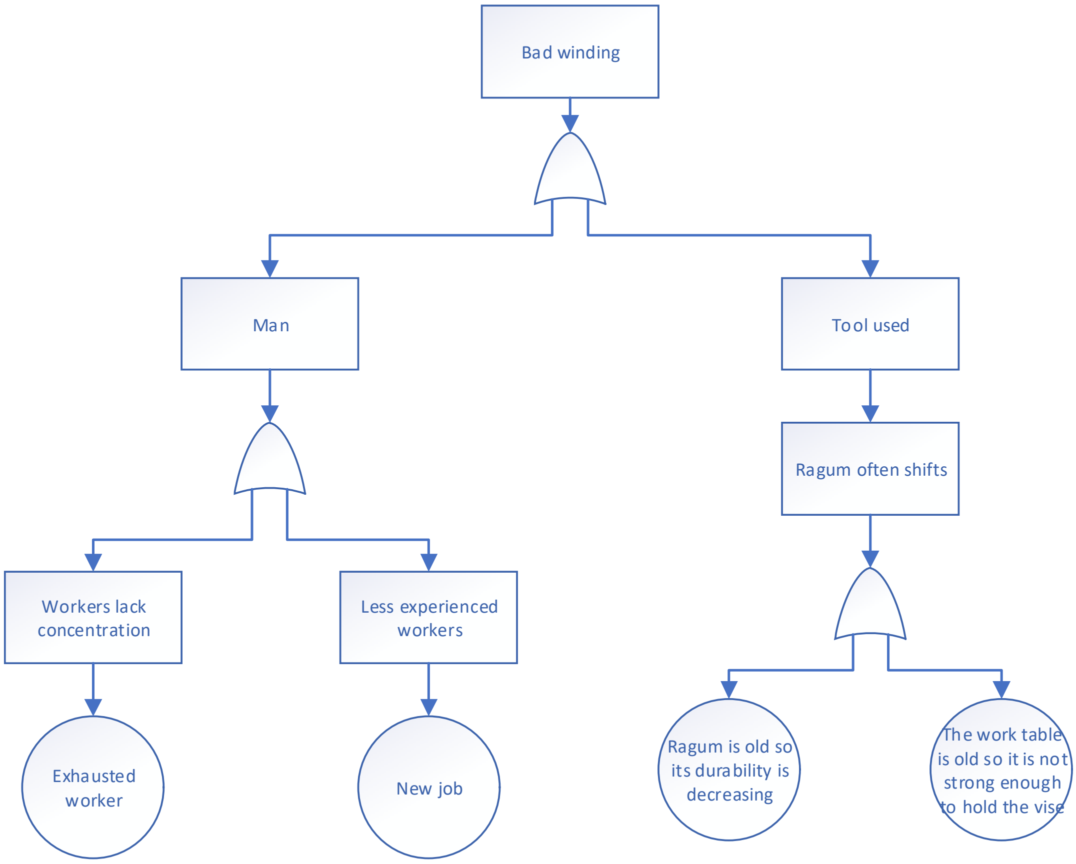

Figure 3 FTA Winding Bad

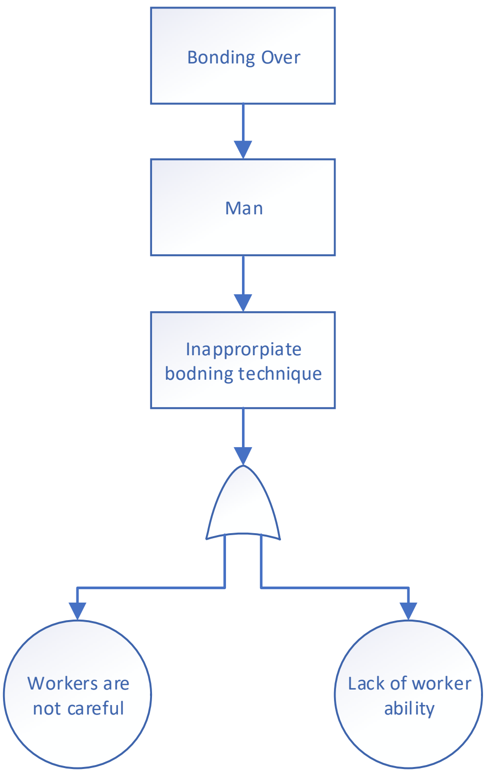

Figure 4 FTA Bonding Over

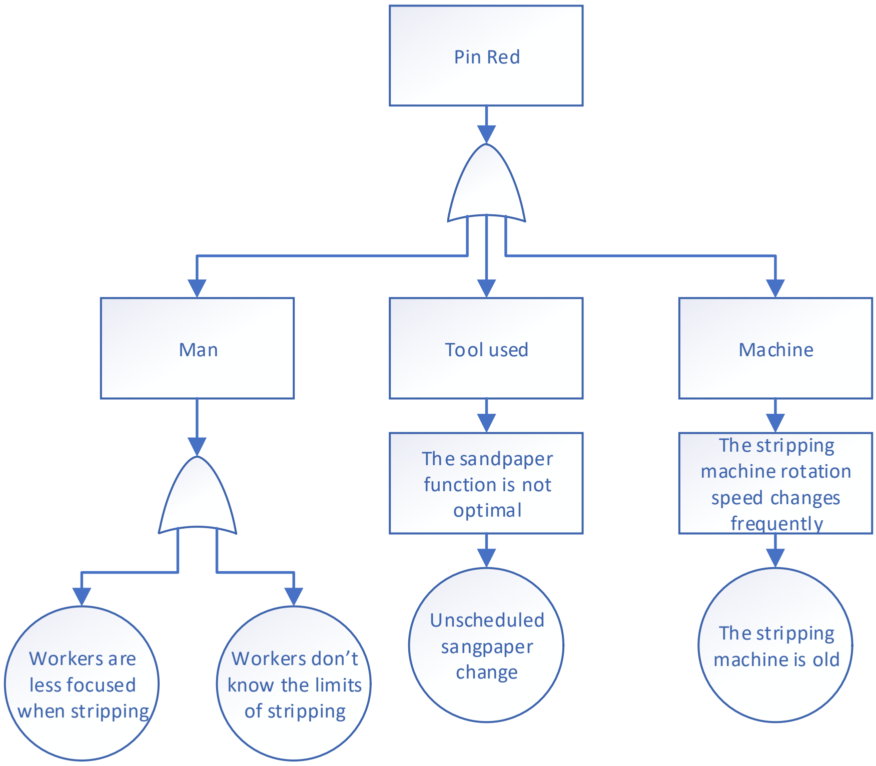

Figure 5 FTA Pin Red

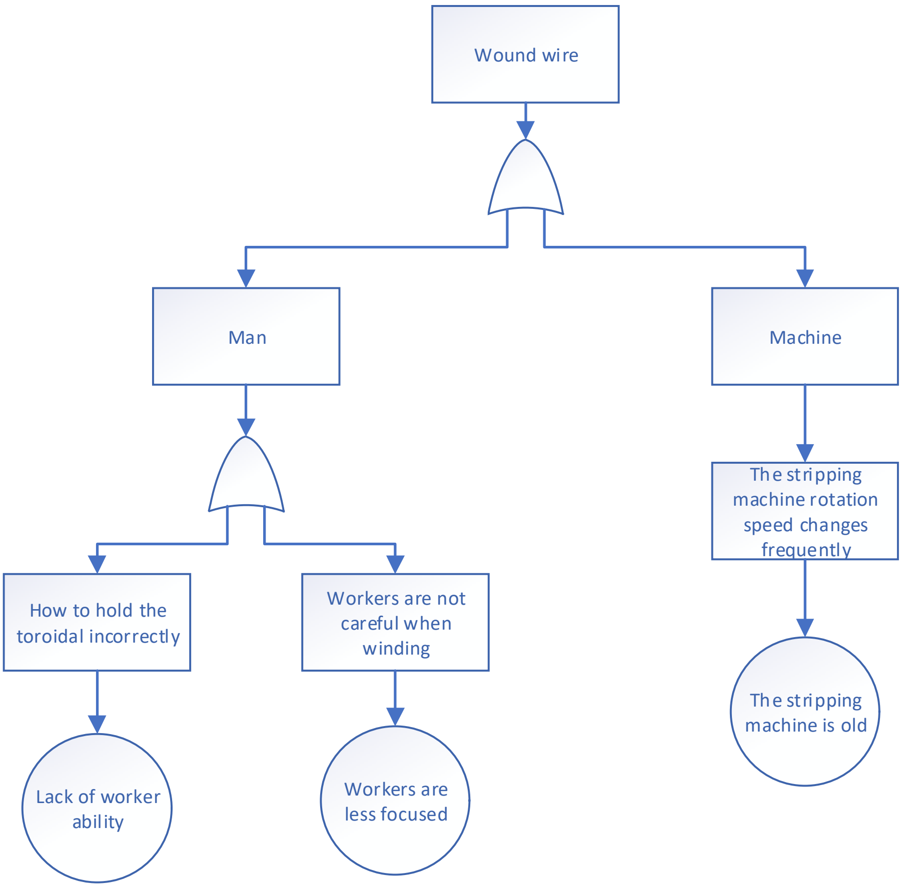

Figure 6 FTA Wire Wound

4.3 Calculation of RPN Value in FMEA

After knowing the mode of failure and its causes that occurs in toroidal inductor product, the subsequent step is to rate the scale of severity, detection, and occurrence. Determination of the rating scale of the level of seriousness (severity) is used to find out how serious the consequences will be if the disability occurs. After rating the scale of severity, the next step is to rate the scale of the value of the probability of failure (occurrence). Determination of this occurrence value scale is done to find out how often the defect occurs by looking at the existing failure modes. This assessment is carried out objectively based on the data available in the mode of failure. The phase of rating the scale of value of detection level is carried out to predict how often defects occur. This assessment is carried out through discussions with the company, namely by the head of the production department. This assessment is based on the potential causes obtained using the FTA method and adapted to the control processes carried out by the company at this time.

After performing the severity rating, occurrence rating, and rating of detection, calculating the value of RPN (Risk Priority Number) becomes the subsequent step to be taken. The RPN value calculation is conducted to set the priority of repairs according to the peak value. The largest values of RPN are sorted to the smallest value so that it can be seen what improvements must be made first. The FMEA documentation outcomes are shown in Table 1 which presents the top RPN value as a reference for enhancement.

Table 1 FMEA documentation results

Function/ Process	Potential Failure Mode	Potential Failures Effect	Potential Causes	Current Control	Severity (S)	Occurrence (O)	Detection (D)	RPN	Rank
Winding	Winding Loose	The toroidal function is not optimal	New job	No regular training schedule	7	5	5	175	4
			Worker fatigue	Supervision from the head of the production			6	210	2
			Ragum is old	Ragum check periodically			3	105	10
			The desk is old	Checking the workbench regularly			2	70	14
	Bad Winding	The product shape is not up to standard	Worker fatigue	Supervision from the head of the production	6	5	6	180	3
			New job	No regular training schedule			5	150	6
			Ragum is old	Ragum check periodically			3	90	12
			The desk is old	Checking the workbench regularly			2	60	15
Bonding	Bonding Over	Causing a glob of glue on the toroid	Workers are not careful	Supervision from the head of the production	5	4	6	120	8
			Lack of worker ability	No regular training schedule			5	100	11
Stripping	Red Pin	The toroidal function is not optimal	Workers are less focused when stripping	Supervision from the head of the production	7	4	6	168	5
			Workers don't know the limits of stripping	No regular training schedule			5	140	7
			Unscheduled sandpaper change	Inspection by workers			2	56	16
			The stripping machine is old	Regular machine checks and repairs			3	84	13
Winding, Stripping	Wound Wire	Toroidal can induce other components around it	Lack of worker ability	No regular training schedule	9	4	5	180	3
			Workers are less focused	Supervision from the head of the production			6	216	1
			The stripping machine is old	Regular machine checks and repairs			3	108	9

5 Result analysis

This study combines the FTA and FMEA methods to reduce defects in toroidal products in the company. FTA is used to determine the cause of defects in each failure mode. While FMEA is used to appraise the risk of each mode of failure so that improvements can be prioritized.

The causes of defects in toroidal products are dominated by humans/workers, machines, and tools used during the production process. These three factors are the main factors causing the failure. While the results from FMEA are the main priority for repairing the wound wire of mode of failure with a value of RPN 216 with the cause of workers or humans being less focused. The lowest RPN value is in the red pin mode of failure with a value of 56 which is caused by the absence of a sandpaper replacement schedule. Then a proposed improvement is made for every mode of failure according to the priority of improvement from the highest to the lowest RPN value.

Some suggestions for enhancement that can be provided are increasing supervision from the head of production for employees, providing additional rest time for workers, conducting training, installing display limits for correct stripping, repairing stripping machines, replacing vise, making repairs to worktables andsandpaper replacement schedule. This improvement proposal was made to increase efficiency in the production of toroidal inductors.

After the proposed improvement was implemented by the company, the percentage of defects fell to 1.25%. So that the improvements made are considered sufficient to increase efficiency in the production of toroidal inductors, although the implementation of this proposed improvement cannot be done entirely. The implementation of the new improvements made by the company is in the form of increasing supervision, providing rest periods, installing stripping limit displays, repairing worktables, and regular sandpaper replacement schedules.

6 Conclusions

According to the outcomes of research that has been conducted, the researchers draw the conclusion that the identification results of FTA (Fault Tree Analysis) are known that the factors that cause defects in toroidal products include humans, machines, and tools used. According to the outcomes of RPN values obtained in the process of making FMEA, the suggestions given include:

a. Increase the supervision of the head of the production.
b. Provide additional rest time for workers.
c. Conduct regular training.
d. Installing border display doing stripping.
e. Stripping machine repair.
f. Perform a vise replacement.
g. Workbench repair.
h. Make a sandpaper change schedule.

Companies must make improvements to human flows and ensure tools and materials are in optimal condition. Therefore, the logistics factor of the material must be given more attention by the manufacturing company

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