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Process improvement design at PT URW using failure mode and effect analysis

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Abstract PT URW is a company engaged in the textile sector that processes yarn into semi-finished fabrics. Such is the case that PT URW has a problem with its waste materials. To address this, the researcher has implemented the method of failure mode and effect analysis (FMEA). In data collection and processing, the researcher defined the problem, collected data, took measurements using the critical waste method, and interpreted the data into the Pareto Chart. The area that had the greatest value was continued to the analysis stages of critical waste analysis, FMEA analysis, and alternative solutions. The research was concluded by providing corrective solutions based on the potential causes that had been found in the previous stage and by validating the formed planned improvements.

1. Introduction

Industry 4.0 was marked by the emergence of cyber-physical and manufacturing collaboration [1]. 4 designs exist within Industry 4.0, namely interconnection, information transparency, technical assistance, and centralized decisions [1]. One of the sectors that are quite affected by the development of the Fourth Industrial Revolution is textile [2]. The textile industry is one of the largest manufacturing industries present in Indonesia [3].

PT URW, located in Central Java-Indonesia, is a textile company that produces semi-finished fabrics that are woven from threads. The production process begins with the warping process through P1, followed by the starching process through P2, then the drawing-in process, and ends with the weaving process through 2 types of machines, namely W1 and W2. PT URW is committed to making improvements by implementing the axioms of Industry 4.0. Having said that, the manufacturing system improvement process has not run optimally. This can still be seen from the waste produced in the form of yarns with details as follows:

Table 1. Waste PT URW Production Area Waste Production in 2020.

No	Month	Waste (kg)
1	October	8711.219
2	November	8499.438
3	December	7023.26

Based on the data above, it can be seen that PT URW encounters a problem in implementing lean manufacturing in its production process. Contrary to lean manufacturing, PT URW uses materials inefficiently in its mass production (Womack, et al, 1990 in Putra, 2017). The waste produced in the form of yarns found on the production floor is significant. Accordingly, the researcher had taken an interest in conducting research related to the improvement of the production process that runs within PT URW using the Failure Mode and Effect Analysis (FMEA) method. Failure Mode and Effect Analysis (FMEA) is a technique used to find, identify, and eliminate potential failures, errors, and problems of a system, design, and process before a product reaches the consumer [5]. Based on the above problems, the problem formulated and discussed in this study is how to reduce potential failure as a result of waste production. The purpose of this study is to identify sub-waste occurrences and the potential causes of the waste that arise along with corrective solutions. In theory, the Failure Mode and Effect Analysis (FMEA) method can provide a solution to solve problems related to yarn waste generation problems.

2. Methodology

Wasteful practice, often called Muda in Japanese, is an activity that squanders resources either through spending additional time or costs that adds little to no value to the activity [6]. In manifesting Lean Manufacturing, one approach that can be used is the Failure Mode and Effect Analysis (FMEA). Vinoth and Raghuraman (2013) used FMEA in their research and succeeded in reducing waste [7].

Failure Mode and Effects Analysis (FMEA) is one of the failure analysis methods applied in product development, system engineering, and operational management [8]. FMEA is a follow-up method to risk management and proposed continuous improvement, making it a key to developing a product or process [9]. Failure mode and effects analysis is a set of instructions derived from the form used to identify and prioritize potential problems. Using FMEA, a company will be able to make improvements and focus its energy and existing resources on prevention, response plan development, and monitoring [4].

There are two domains of FMEA, namely the within the field of design (Design FMEA) and process (Process FMEA). Design FMEA will help eliminate design-related failures, e.g., failures due to improper strength, unsuitable materials, etc. Whereas, Process FMEA will eliminate failures caused through changes in process variables, for instance, conditions outside the specified specification limits such as improper size, inappropriate texture and color, inappropriate thickness, and others [10].

FMEA has various purposes in its formation, including the following [11]: to identify failure modes and their level of effect, to identify critical and significant characteristics, to rank potential design and process deficiencies, as well as help engineers, focus on the prevention of problems. FMEA has several steps in its creation which are expounded in more detail in [12]. There are 3 variables in obtaining RPN, namely severity, occurrence, and detection. Severity is an assessment of the seriousness of a failure effect that arises. Occurrence is the degree of possibility that the cause will occur and result in a form of failure during the life of the product. The occurrence value is presented in rate adjusted to the estimated frequency and or the cumulative number of failures that can occur. Detection is associated with the current control. Detection is a measurement of the ability to control failures that may occur [13].

2.1 Research methodology

The data collected in this study were quantitative data and qualitative data. The qualitative data was obtained through interviews and field observations. The quantitative data was data recapitulation of yarn waste produced. The population in this study was the entire waste material found on the production floor. The sample in this study is the amount of waste material in the form of yarn taken in the production area from October to December 2020. The sampling technique in this study used the non-probability sampling method [14]. Data were taken using the non-probability sampling technique based on the theory of 7 wastes from

October 2020 to December 2020. The data processing in this study used the FMEA method to obtain the most critical sub-waste and followed up with corrective solutions.

2.2 Data collection
The production process begins with the supply of threads from the supplier as a raw material in the fabric manufacturing process. The threads then will be sent to 3 places, namely P1 for warp yarn, and P4 and W1 for weft yarn. The yarn processed in P1 undergo the warping process then continued onto P2 for starching. The yarn then goes to P3 for the drawing-in process before going directly to W1 or W2 for the tying-in process that transforms it into cloth. The finished fabric will go through an inspection process first before being packaged and put into G to be sent to the supplier. From the findings in the field, there is a significant amount of yarn waste produced that generates a considerable loss for the company. The yarn waste data collected from October 2020 to December 2020 data are as follows:

Table 2. Data on waste materials found on the production floor.

Area	Sub-waste	October	November	December	Total	Average
G	Yarn threads	0	0	0	0	0
P1	Yarn threads	93.2	86.2	115.9	295.3	98.43333
P2	Long starched thread	994	1351.7	471.5	2817.2	939.0667
	Long unstarched thread	832.2	651.4	804.8	2288.4	762.8
W1	Fabric fringes	2496.6	2787.8	2574.9	7859.3	2619.767
	Long threads	228.1194	364.8	275.6	868.5194	289.5065
	Yarn threads	432.2	155.4	34.4	622	207.3333
W2	Fabric patches	1121.6	1125.1	970.7	3217.4	1072.467
	Yarn threads	254.8	239.6	232.8597	727.2597	242.4199
P3	Yarn threads	25.6	0	0	25.6	8.533333
P4	Yarn threads	2232.9	1780.2	1542.6	5555.7	1851.9
I	Long threads	0	0	0	0	0

The table above presents the distribution of waste material in each production area based on the type of waste material produced. This data was processed to identify the most problematic area and sub-waste so that solutions can be given.

2.3 Data processing
Data processing was done using the critical waste method. The critical waste measurement method measures waste based on the value lost due to the presence of waste. The lost value is calculated by multiplying the price of yarn per kg by the weight of the yarn produced as wastes. The calculation results are shown in the Pareto Chart presented in Figure 1 as follows:

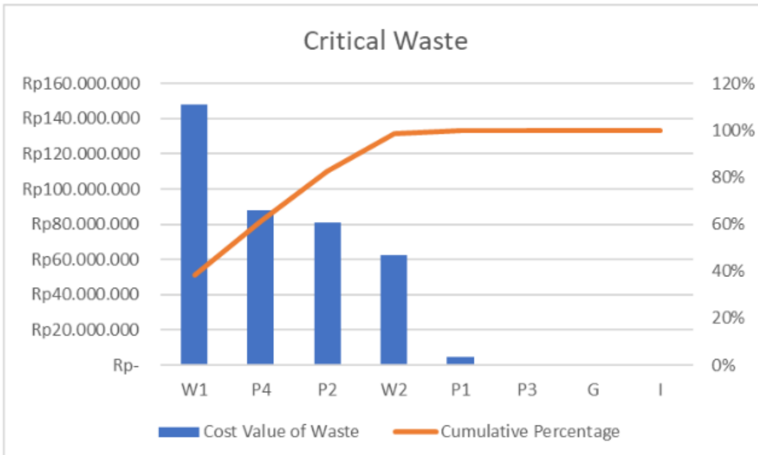

Figure 1. Critical waste pareto chart.

Based on the critical waste data, 5 production areas produced the largest critical waste, namely W1 with a wasted value of Rp. 148,038,808, the P4 area with a wasted value around Rp. 87,965,250, the P2 area with a wasted value of Rp. 80,838,667, and the W2 area with total value wasted at Rp. 61,780,039, and the P1 are with a total value wasted at Rp. 4,675,583

3. Results and discussion

The FMEA method is a method used to measure the value of waste produced categorized into sub-waste types based on RPN. The RPN value is generated by multiplying the scores of 3 elements, namely severity, occurrence, and detection. The FMEA is formed based on information from the fields within the company, i.e., the head of the preparation field, the head of the W1 field, and the head of the W2 division. The data processing results using FMEA in critical areas that have relatively high RPN values can be seen in Table 3.

The alternative solution is an advanced method inherent to FMEA. Alternative solutions are used to provide solutions based on potential causes for each failure that cause the production of waste [5]. Alternative solutions are used to propose improvements based on the highest RPN value using the FMEA method as can be seen in Table 4.

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Table 3. Failure mode and effect analysis for critical area.

Area	Sub Waste	Potential Failure Mode	Potential Failure Effect	Sev	Potential Causes	Occ	Detective Control	Det	RPN
P2	Long starched thread	Damaged threads, etc	Some production material goes to waste	6	Operator errors in setting the machine: SPU, press, speed, viscosity, REF, temperature, and path settings.	6	Visual detection equipped with standardized settings	6	216
			Minor disruption to the production line	6	Operator errors in setting the machine: SPU, press, speed, viscosity, REF, temperature, and path.	6	Visual detection equipped with standardized settings	6	216
	Long unstarched thread	Thread not starched	Some production material goes to waste	6	Thread is used as a start and final feed because there is no thread connection tool	5	Detection based on human visual and visual standards only	6	180
P4	Yarn threads	Weft yarn not used optimally	Some production material goes to waste	6	The shuttle cannot process pallet threads optimally as the shuttle cannot carry the pallet threads strongly.	6	Detection through needle filler with a low detection rate	6	216
			Minor disruption to the production line	6	The shuttle cannot process pallet threads optimally as the shuttle cannot carry the pallet threads strongly.	6	Detection through needle filler with a low detection rate	6	216
W1	Woven fabric fringes	Thread is handled	Some production material goes to waste	6	No leno thread holder as a weft thread holder	7	A control consisting of only standardization of the use of fringe threads on W1	9	378
	Long thread	Thread is unwoven	Some production material goes to waste	6	Thread is used as a start and final feed because there is no thread connection tool and error in the machine setting	5	Detection carried out through standardization of thread installation	4	120
			Minor disruption to the production line	6	Thread is used as a start and final feed because there is no thread connection tool and error in the machine setting	5	Detection carried out through standardization of thread installation	4	120
W2	Yarn threads	Threads cannot be processed in weaving and go to waste	Waste material	6	Tying-in process and failure due to insufficient standard of threads from the starching process	5	Detection through standardization of machine settings	4	120
			Production interruption	6	Tying-in process and failure due to insufficient standard of threads from the starching process	5	Detection through standardization of machine settings	4	120

Table 4 Alternative solutions.

Area	Sub waste	Potential Cause	Expectation	Alternative Solution
W1	Fabric fringes	No Leno thread holder for the weft thread resulting in the need for large quantities of Leno thread and a longer weft thread at each feeding point	Temple ring able to hold and support leno thread	Temple ring can be improved by adding texture to the back of the temple ring to allow it to hold the Leno threads
			A small amount of fringe waste produce	The weft thread is set to be shorter
P4	Yarn threads	The shuttle cannot process pallet threads optimally as the shuttle cannot carry the pallet threads strongly (pallet thread is not properly aligned at feed point)	The shuttle is facilitated with stronger pallet clamps (to keep the pallet from moving)	Reinforcing clamp in the shuttle for the pallet
			The palette setting process is convenient	The existing clamp can be designed for ease in the installation process
		The shuttle cannot process pallet threads optimally as the shuttle cannot carry the pallet threads strongly (pallet thread is not properly aligned at feed point)	The filler needle is not too sharp so as not to damage the weft thread	Redesign of filler needle with a thicker cone (3 mm)
P2	Long starched thread	Operator errors in setting the machine: SPU, press, speed, viscosity, REF, temperature, and path settings.	The operator is skilled in setting starch machines (SPU, press, speed, viscosity, REF, temperature, and path)	Conducting education and implementing setting standards for SPU machines, press, speed, viscosity, REF, temperature, and paths
	Long unstarched thread	Thread is used as a start and final feed because there is no thread connection tool	Waste in the initial pull at each change in series is low (long unstarched thread)	Provision of thread connecting device for every series change
W2	Fabric patches	Initial and final feed pull, machine settings in the production process used as standard in the company	-	-

4. Conclusion

To minimize yarn waste material production, the researcher uses FMEA to identify and find solutions to existing problems. By using the critical waste calculation method and the Pareto chart, several areas with the largest wasted values were found, namely areas W1, P4, P2, W2, and P2. After an in-depth analysis using the FMEA method, it was found that the sub-waste with the largest RPN value was the fabric fringe sub-waste in the W1 area with an RPN value of 378, the yarn threads sub-waste in the P4 area with an RPN value of 216, the long-starched thread sub-waste in the P2 area with RPN value of 216, the long unstarched thread sub in the P2 area with RPN value of 180, and fabric patches sub-waste in the W2 area with RPN value of 144.

The proposed improvements in the present study for the problems identified are the redesigning of the temple ring tool, the redesigning of the shuttle on the W2 machine, the implementation and education on the standard settings of the machines in P2, and the provision of thread connecting device in P2.

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