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Analysis of Priority Improvement in Draft Quality of Sizing Using Grey Theory in FMEA

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A B S T R A C T

Draft quality is a crucial problem in the sizing section. There were 3889 warp yarn breaks for six months. The study aims to decrease quality draft defects by applying the grey theory in the traditional FMEA. After analyzing the flow process, 41 potential causes (PC) were found from 12 potential failure modes in 7 areas. There is no significant difference in the top 5 rankings of the RPN assessment on traditional FMEA and grey theory. However, there is a slight difference in ranking on 5 PC. The first priority (RPN= 48; GR=0.588) is in the beam shaft with the creel unaligned in the beam installation (pneumatic piston not parallel). The last priority (RPN= 4; GR=0.857) is a less oiling. This research can recommend an improvement sizing process based on the proposed repairs or maintenance list, using the Grey theory in the FMEA method to decrease the weaving industry defect rate.

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1. INTRODUCTION

The textile sector has made significant contributions to the global economy over time following available studies that have produced employment opportunities, generated income, and spurred economic growth (Ali, Al Masud, Hossain, Islam, & Shafiul Alam, 2024; Nabi, 2022; Al Masud, Hossain, & Biswas, 2021). In the textile industry, “Weaving” is one of the most prevalent fabric manufacturing methods where the process is divided into three primary stages: warping, sizing, and weaving (Ahmed & Uddin, 2023). Sizing is a critical phase in textile production that gives warp yarns extra protection (Ni et al., 2023). Weaving on a modern loom is difficult without sizing (Ayele & Abay, 2023; Turukmane, Gulhane, & Patil, 2019; Devare, Turukmane, Gulhane, & Patil, 2016). The sizing process prevents projecting hairs from tangling with each other. It improves the yarn's resistance to scratches by putting an adhesive (starch) paste on its surface and immersing the warp yarns in the size paste with a sizing machine. It is done to increase its tenacity, fatigue resistance, and elasticity, allowing it to survive the demands of the weaving process (Gandhi, 2020). Machines are the primary means of carrying out the production process, so the machines used must be in good condition during the production process (Pujianto, Yulianto, Bintang, & Pramesti, 2023; Pravitasari, Kusumadewi, & Barat, 2023). Therefore, machine maintenance is needed to ensure that the system and all components can perform effectively (Rahayu, 2016), so that can prevent losses such as decreased production quality and quantity, as well as machines being impaired and unable to function (Afdal & Linarti, 2023; Febianti, Ferdinant, Wahyuni, & Riyani, 2020).

PT XYZ is a company that produces grey fabric in the weaving industry. Any sector industry focused on maximizing output while preserving the quality of the product so that it can meet the cost and quality criteria of both domestic and foreign markets and customers. To compete, the textile business is working to boost production while producing excellent products at an affordable price (Jahangir & Hossain, 2023). However, 563 warp beams had problems, and there were 3889 warp breaks in the creel, size box, and reeds areas from January to June 2023, which caused the number of warp breaks during the weaving process to be very high. So, it is essential to understand and overcome the causes of yarn breakages to increase production efficiency (Rashedul Islam, 2023), and obstacles that disrupt the production process must be removed so that it can run smoothly (Pujianto, 2021). Machine stoppages become more costly given the massive loss of capacity (Jahangir & Hossain, 2023).

The factor causing the high warp breakage is non-standard elongation yarn "draft quality." Amid the sizing, the yarns are held under tension, resulting in a minor permanent stretch and decreased extensibility or elongation at the breaking limit of sized yarns. The yarn's extensibility decreases as its stretch increases. It leads to a higher level of end breakage while weaving (Ayele & Abay, 2023; Gandhi, 2020). Several factors, including the draft sizing machine setting factor, influence non-standard draft quality. Therefore, accurate sizing enhanced durability to abrasion with minimum degradation of warp yarn elongation (Genene Abay & Ayele, 2023). Therefore, process control to boost product quality must be carried out by enhancing draft quality in the sizing section because weaving preparatory like sizing section has an essential involvement in the level at which goods are produced in the fabric manufacturing industry (Rajput, Gulhane, Turukmane, & Basak, 2018).

One of the quality control in lean manufacturing tools to control the production process is Failure Modes and Effects Analysis (FMEA) (Palange & Dhatrak, 2021) as a technique for determining the cause of a failure and assessing the repercussions and risk factors that arise in a product or process (Fajriah, Mahfud, & Hayati, 2023). Traditionally, any potential failure modes are assessed by computing a Risk Priority Number (RPN) by multiplying O *(Occurance)* $\times S$ *(Severity)* $\times$ *D (Detection)*. A more severe RPN or higher than others is regarded as more dangerous and, thus, allocated more priority for resolution (Ju et al., 2024). However, considerable critiques have been leveled at the standard FMEA since it cannot assign varied weights to the risk factors O, S, and D, and so could be less appropriate for the actual circumstance. Scholars have developed improved FMEA approaches to address its flaws by combining several multi-criteria decision-making (MCDM) approaches (Ouyang, Che, Yan, & Park, 2022). To enhance and avoid these criticisms of standard FMEA, grey theories are added into FMEA, making the outcomes more feasible and adaptable in reflecting what happens (Zhou & Thai, 2016).

This study is a study case to propose improvement priorities that can be used for decision-making concerning the maintenance of various components on the sizing machine. The aim is to enhance draft quality in the sizing section to reduce defects and machine stoppages that cause poor production targets. The novelty of this study is to make quality and process improvements by applying grey theory in FMEA to reduce the defect rate of the preparatory process on the sizing section of the weaving industry in textile companies.

2. LITERATURE REVIEW

Various industries have extensively implemented Failure Mode and Effect Analysis (FMEA) since it was first introduced in the 1960s in the aerospace industry (G. Huang, L. Xiao, W. Pedrycz, G. Zhang, & L. Martinez, 2023) as a potential and structured analysis tool to enhance safety and reliability in the system (Wan et al., 2024) and contributes a vital part in detecting failure (Ma et al., 2024). The most crucial and significant failure modes will then be evaluated, and their performance will be considered following the implementation of the corrective actions (Nasrallah et al., 2023). In actuality, the FMEA method has shown to be a helpful and strong instrument in lowering manufacturing costs, accelerating the product development cycle, and enhancing product reliability (Huang, Guo, Shi, & Liu, 2023). However, traditional FMEA methods can produce imprecise evaluation results due to intrinsic flaws and limitations (Rong et al., 2024) that Limit their effectiveness and versatility (Wan et al., 2024). Making precise risk factor ratings tricky to establish because ambiguity and randomness are prevalent throughout the assessment from different expert interpretations of qualitative terms (Li et al., 2024), and the significance of risk parameters has not been thoroughly weighed (Rong et al., 2024; Liu, Chen, Duan, & Wang, 2019; Park, Park, & Ahn, 2018). Therefore, to overcome the constraints of traditional FMEA procedures in complex contexts, many FMEA approaches have been integrated with other methods in recent years (Ma et al., 2024), such as combining with Grey theory, which was first proposed by Chang, Liu, & Wei (2001). Adding grey theory to the ordinary FMEA allows professionals to assign relative priority because they can demonstrate ambiguity (Shaju, Babu, & Thomas, 2023) to the risk elements (Zhou & Thai, 2016) depicted to be potential failure causes (Moon, Oh, Venture, Kim, & Yoon, 2013). Grey theory is prominent in the field of decision-making because it is also commonly used in enhanced RPN analysis (Wang, Zhang, & Yang, 2019). Previous research has used grey theory by integrating it with traditional FMEA to analyze in estimating the failure of oil tanker equipment (Zhou & Thai, 2016), CNC Lathes (Wang et al., 2019), humanitarian supply chain (Minguito & Banluta, 2023).

3. RESEARCH METHOD

This study develops a quantitative failure mode metric for an existing sizing machine in preparatory weaving by approaching the Grey Theory in the FMEA technique. The framework of the proposed Grey Theory in FMEA approach can bee seen in the figure 1. FMEA can recognize important risk occurrences and drive risk avoidance and handling by examining system failure modes and their consequences, rating system risk variables, and contrasting their risk degrees (Li et al., 2024; Yu, Yang, & Wu, 2023). An FMEA can be completed in various steps, as follows (Ervural & Ayaz, 2023; Ebeling, 2019; Sharma, Kumar, & Kumar, 2005): (1) Determine the system to be evaluated. Gather information on the product, process, and operation. (2) Define and explain observed and expected failure modes and their implications for systems and subsystems. (3) Evaluate the most likely cause(s) of each failure. (4) Examine the consequences of every failure on the structure from an overall standpoint. (5) Compute the criticality using RPN by assigning a scale range between 1 and 10 for each risk factor, i.e., severity (S), occurrence (O), and detection (D), then multiplying the three risk factors (Ouyang et al., 2022). Occurrence (O) refers to potential failure modes, Severity (S) refers to assessment failure effects, and Detection (D) refers to the likelihood of not discovering the failure mode (Ju et al., 2024). At this stage, the assessment is carried out based on expert estimates.

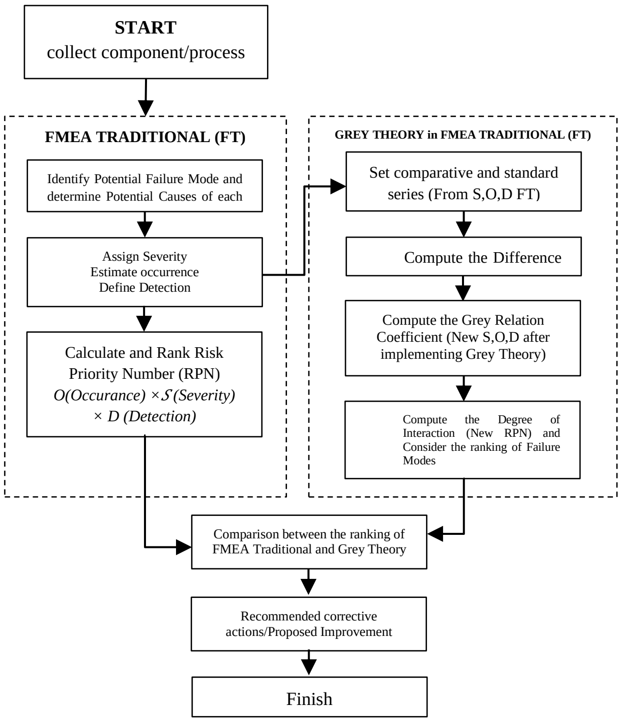

Figure 1. The study framework

This study established the Grey Theory to address FMEA weaknesses and validate RPN results. Grey theory generally applies to multi-input, not complete, or unclear information (Minguito & Banluta, 2023; Chang, Liu, & Wei,

2001) and can capture unpredictability in an alternate manner than fuzzy logic (Shaju et al., 2023). The stage of developing a grey theory approach to grading the failure modes detected throughout the FMEA process follows (Zhou & Thai, 2016):

1. Set comparative and standard series.
   Comparative series are drawn from previous traditional FMEA S, O, and D assessments, and to limit the potential risk, the values of all selection factors must be as little as feasible; consequently, the standard series can be set from the smallest value, as follows (Chang et al., 2001):
   $$X_0 = [X_0(1)X_0(2) \dots X_0(k)] \quad (1)$$
2. Compute the Difference Sequence
   The equation is as follows:
   $$\Delta_{0j}(k) = \left|\left|X_0(k) - X_j(k)\right|\right| \quad (2)$$
   Which measures the difference between comparative and standard series (Minguito & Banluta, 2023).
3. Compute the grey relation coefficient.
   $$\gamma_{0j}(\mathrm{k}) = \frac{\Delta\mathrm{min} + \varsigma\Delta\mathrm{max}}{\Delta_{0\mathrm{j}}(\mathrm{k}) + \varsigma\Delta\mathrm{max}} \quad (3)$$
   Where, $\varsigma \in [0,1]$, the differentiating coefficient (ς) is usually set to 0.5 (Ouyang et al., 2022) (Zhou & Thai, 2016)
4. Compute the degree of interaction
   k = 1, 2, ...n, Equation as following (Zhou & Thai, 2016) :
   $$\Gamma(x_{0,}x_i) = \frac{1}{n} + \sum_{k=1}^{n} \gamma\ (x_0(k), x_i(k) \quad (4)$$
   The cause's influence decreases as the degree of link increases. As a result, the failure mode with the most minor grey relationship coefficient should receive the highest priority.
5. Consider the ranking of Failure Modes

4. RESULT AND DISCUSSION

Several cross-function members, including the maintenance engineer, quality assurance, and head of preparatory weaving, fill FMEA's traditional assessment. Based on the works of the FMEA team, there are 41 potential causes (PC) from 12 potential failure modes in 7 areas. Table 1 shows the information about traditional FMEA assessment.

Table 1. FMEA Traditional Assessment

No	Potential Failure Mode	No	Potential Causes	**S**	**O**	**D**	**RPN**	**Rank**
1	Back creel unfunction	1	Air pressure not set	8	5	1	40	6
		2	Damaged canvas/rusted chain	8	6	1	48	2
		3	beam axle with creel unaligned in beam installati (pneumatic piston unaligned)	8	7	1	56	1
		4	The installation of the break adjustment hole is incorrect	8	2	1	16	25
2	Feeding roll unfunction	5	Hard rubber	4	4	1	16	26
		6	Broken axle	5	3	1	15	27
		7	Bearing damaged	5	5	1	25	15
		8	dirty or defective	4	2	1	8	35
	Dancing roll unfunction	9	Broken axle	5	2	1	10	33
		10	Bearing damaged	5	4	1	20	19
		11	dirty or defective	4	3	1	12	30
3	Squeezing roll unfunction	12	Hard rubber	4	6	1	24	17
		13	Bearing damaged	5	7	1	35	10
		14	Broken axle	5	6	1	30	13
		15	Pneumatic seals are worn	4	5	1	20	21
		16	dirty or defective	4	7	1	28	14
	Immersion roll unfunction	17	Bearing damaged	3	5	1	15	28
		18	Broken axle	3	4	1	12	31
		19	dirty or defective	3	3	1	9	34
		20	Hard chrome cracked	3	2	1	6	37
	Pulley interchange velocity (PIV) unfunction	21	Gearbox PIV damaged	6	7	1	42	5
		22	Setting damaged	6	6	1	36	7
		23	less oiling	4	1	1	4	40
4	Wet Splitting Unfuction	24	Bearing damaged	5	5	1	25	16
		25	Broken axle	4	3	1	12	29
		26	rusted chain	5	1	1	5	38

		27	dirty or defective	4	8	1	32	11
		28	Teflon peeling	4	9	1	36	8
5	Dryer cylinder unfunction	29	Worn Chain	4	5	1	20	22
		30	Condensation	3	2	6	36	9
		31	Teflon peeling	3	6	1	18	24
6	Roll tension dey area Unfunction	32	dirty or defective	4	2	6	48	3
		33	Bearing damaged	5	2	1	10	32
		34	Broken axle	5	1	1	5	39
	Splitting Rod Unfunction	35	bent roll	3	8	1	24	18
		36	dirty or defective	3	2	1	6	36
7	Pulley interchange velocity Head (PIVH) unfunction	37	Gearbox damaged	6	5	1	30	12
		38	Setting damaged	6	3	1	18	23
		39	less oiling	4	1	1	4	41
	Winding Tension Unfuction	40	Bearing damaged	5	4	1	20	20
		41	Load Cell damaged	5	9	1	45	4

Set Comparative and Standard Series and Differences between Series

The comparative series is taken from the traditional FMEA assessment, and then the standard series can be determined from equation (1), $X_0 = [X_0(1) X_0(2) \dots X_0(k)] = [1,1,1]$. The difference between the two variables is calculated by subtracting the comparative series from the standard series based on equation (2). Example: Δ_{01} (1) =8-1=7; Δ_{02} (1) =5-1= 4; Δ_{02} (28) = 9-1=8; Δ_{03} (1) = 1-1=0

Compute the Grey Relation Coefficient

Resolving the grey relation coefficient under equation (3), the Δmin=8 and Δmax=0 with ς = 0.5. example:

$$\gamma_{01}(1) = \frac{0 + 0.5x8}{7 + 0{,}5x8} = 0.363$$

$$\gamma_{02}(1) = \frac{0 + 0.5x8}{4 + 0{,}5x8} = 0.500$$

$$\gamma_{03}(1) = \frac{0 + 0.5x8}{0 + 0{,}5x8} = 1.000$$

Compute the Degree of Interaction

Resolving degree of interaction under equation (4). Three choice variables are equally essential. The equation that follows can be used:

$$\Gamma\left(x_{0,}x_i\right) = \frac{1}{3} + \sum_{k=1}^{3}(0.363 + 0.5 + 1.0 = 0.621$$

Comparison between the ranking of FMEA Traditional and Grey Theory

To assess the suggested FMEA technique's strength and capabilities, we conducted a comparative discussion with two different FMEA techniques. Table 2 and Figure 2 show the comparative ranking results utilizing the FMEA and Grey theory techniques. Although their rankings vary slightly in 5 PC (PC4, PC5, PC13, PC 28, PC 30), the most critical issues are similar, including the top. All improvements are proposed for each PC to minimize defects in the sizing process, and practical approaches are designed to remove the PC. Recommended proposed improvement can be recognized in Table 3.

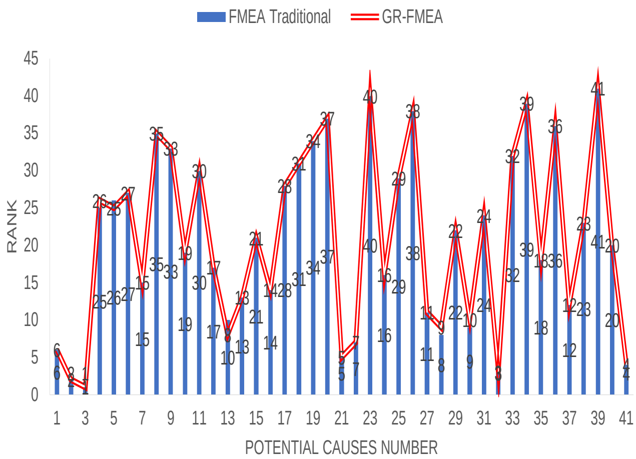

Figure 2. Ranking results of the two FMEA techniques

Table 2. Comparison results of the two FMEA techniques

FMEA Traditional						Grey Theory				
PC	S	O	D	RPN	Rank	S	O	D	GT	Rank
PC1	8	5	1	40	6	0,364	0,500	1,000	0,621	6
PC2	8	6	1	48	2	0,364	0,444	1,000	0,603	2
PC3	8	7	1	56	1	0,364	0,400	1,000	0,588	1
PC4	8	2	1	16	25	0,364	0,800	1,000	0,721	26
PC5	4	4	1	16	26	0,571	0,571	1,000	0,714	25

PC6	5	3	1	15	27	0,500	0,667	1,000	0,722	27
PC7	5	5	1	25	15	0,500	0,500	1,000	0,667	15
PC8	4	2	1	8	35	0,571	0,800	1,000	0,790	35
PC9	5	2	1	10	33	0,500	0,800	1,000	0,767	33
PC10	5	4	1	20	19	0,500	0,571	1,000	0,690	19
PC11	4	3	1	12	30	0,571	0,667	1,000	0,746	30
PC12	4	6	1	24	17	0,571	0,444	1,000	0,672	17
PC13	5	7	1	35	10	0,500	0,400	1,000	0,633	8
PC14	5	6	1	30	13	0,500	0,444	1,000	0,648	13
PC15	4	5	1	20	21	0,571	0,500	1,000	0,690	21
PC16	4	7	1	28	14	0,571	0,400	1,000	0,657	14
PC17	3	5	1	15	28	0,667	0,500	1,000	0,722	28
PC18	3	4	1	12	31	0,667	0,571	1,000	0,746	31
PC19	3	3	1	9	34	0,667	0,667	1,000	0,778	34
PC20	3	2	1	6	37	0,667	0,800	1,000	0,822	37
PC21	6	7	1	42	5	0,444	0,400	1,000	0,615	5
PC22	6	6	1	36	7	0,444	0,444	1,000	0,630	7
PC23	4	1	1	4	40	0,571	1,000	1,000	0,857	40
PC24	5	5	1	25	16	0,500	0,500	1,000	0,667	16
PC25	4	3	1	12	29	0,571	0,667	1,000	0,746	29
PC26	5	1	1	5	38	0,500	1,000	1,000	0,833	38
PC27	4	8	1	32	11	0,571	0,364	1,000	0,645	11
PC28	4	9	1	36	8	0,571	0,333	1,000	0,635	9
PC29	4	5	1	20	22	0,571	0,500	1,000	0,690	22
PC30	3	2	6	36	9	0,667	0,800	0,444	0,637	10
PC31	3	6	1	18	24	0,667	0,444	1,000	0,704	24
PC32	4	2	6	48	3	0,571	0,800	0,444	0,605	3
PC33	5	2	1	10	32	0,500	0,800	1,000	0,767	32
PC34	5	1	1	5	39	0,500	1,000	1,000	0,833	39
PC35	3	8	1	24	18	0,667	0,364	1,000	0,677	18
PC36	3	2	1	6	36	0,667	0,800	1,000	0,822	36
PC37	6	5	1	30	12	0,444	0,500	1,000	0,648	12
PC38	6	3	1	18	23	0,444	0,667	1,000	0,704	23
PC39	4	1	1	4	41	0,571	1,000	1,000	0,857	41
PC40	5	4	1	20	20	0,500	0,571	1,000	0,690	20
PC41	5	9	1	45	4	0,500	0,333	1,000	0,611	4

Table 3. Proposed improvement

Area	Item	Potential Effect	Potential Causes	FMEA Traditional		Grey Theory		Proposed Improvement
				PC	Rank	GT	Rank	
Creel Beam Stand	Break creel beam stand	The beam rotation rate is unstable	Beam axle with creel unaligned in beam installation (pneumatic piston unaligned)	PC3	1	0,588	1	Operators are more careful when installing the beam to the creel beam stand
			Damaged canvas/rusted chain	PC2	2	0,603	2	Replace components when damaged and carry out chain maintenance by soaking the chain in diesel so that the chain is flexible so that the chain is not stiff when the chain rusts
Splitting Tension	Roll tension dry area	Cannot conduct yarn	dirty or defective	PC32	3	0,605	3	Carry out daily or periodic checks, clean the roll tension dry area, and repair components by re-sanding defects or rough areas.
Head Stock	Winding tension	Cannot adjust yarn tension	Load Cell damaged	PC41	4	0,611	4	Replacing components
Size Box	Pulley interchange velocity (PIV) size box	Cannot set beam rotation speed	Gearbox PIV damaged	PC21	5	0,615	5	Carry out daily checks and repair damaged components

Creel Beam Stand	Break creel beam stand	The beam rotation rate is unstable	Air pressure not set	PC1	6	0,621	6	Operators must pay more attention to the air pressure, which must comply with the established standards (Wind pressure for the front beam section is 2.5 bar, and wind pressure for the rear section is 3.0 bar)
Size Box	Pulley interchange velocity (PIV) size box	Cannot set beam rotation speed	Setting damaged	PC22	7	0,630	7	Repair components by resetting them
	Squeezing roll	Cannot squeeze the yarn to the maximum	Bearing damaged	PC13	10	0,633	8	Replacing components
Wet Tension	Wetsplittingg	Cannot separate wet starched yarns properly and cannot sleep the thread hairs	Teflon peeling	PC28	8	0,635	9	Repairs by providing Teflonn tips
Dryer Cylinder	Pre-dryer and dryer	Cannot avoid sticky yarns and dry yarns completely	Condensation	PC30	9	0,637	10	Check regularly to see the condition of the condensation water in the dryer cylinder, then provide a steam trap to drain the condensation water
Wet Tension	Wet splitting	Cannot separate wet starched yarns properly and cannot sleep the yarn hairs	dirty or defective	PC27	11	0,645	11	Carry out daily or periodic checks, clean the wet splitting, and repair components by re-sanding defects or rough areas.
Head Stock	Pulley interchange velocity (PIV) head	Cannot set the tension according to the desired requirements	Gearbox PIV damaged	PC37	12	0,648	12	Carry out daily checks and repair damaged components
Size Box	Squeezing roll	Cannot squeeze the yarn to the maximum	Broken axle	PC14	13	0,648	13	Replacing broken axle components (the level of damage is severe) and repairing components by welding (the level of damage is light)
			dirty or defective	PC16	14	0,657	14	Check every day or periodically and clean dirty squeezing rolls and make repairs by re-grinding rough rubber
Feeding Tension	Feeding roll	Yarn tension is unstable	Bearing damaged	PC7	15	0,667	15	Replacing components
Wet Tension	Wet splitting	Cannot separate wet starched yarns properly and cannot sleep the yarn hairs	Bearing damaged	PC24	16	0,667	16	Replacing components
Size Box	Squeezing roll	Cannot squeeze the yarn to the maximum	Hard rubber	PC12	17	0,672	17	Repair components by grinding the rubber squeezing roll (light level of damage), then doing a soft test to see the flatness of the grinding results and replacing the rubber squeezing roll (light level of damage)
Splitting Tension	Splitting rod	Cannot conduct yarn	bent roll	PC35	18	0,677	18	Repair components by straightening bent rolls

Feeding Tension	Dancing roll	Cannot detect yarn tension	Bearing damaged	PC10	19	0,690	19	Replacing components
Head Stock	Winding tension	Cannot adjust yarn tension	Bearing damaged	PC40	20	0,690	20	Replacing components
Size Box	Squeezing roll	Cannot squeeze the yarn to the maximum	Pneumatic seals are worn	PC15	21	0,690	21	component repair
Dryer Cylinder	Pre-dryer and dryer	Cannot avoid sticky yarns and dry yarns completely	Worn Chain	PC29	22	0,690	22	Applying high-temperature cylinder grease once every six months
Head Stock	Pulley interchange velocity (PIV) head	Cannot set the tension according to the desired requirements	Setting damaged	PC38	23	0,704	23	resetting
Dryer Cylinder	Pre-dryer and dryer	Cannot avoid sticky yarns and dry yarns completely	Teflon peeling	PC31	24	0,704	24	Repairs by providing Teflonon tips
Feeding Tension	Feeding roll	Yarn tension is unstable	Hard rubber	PC5	26	0,714	25	Re-rubber
Creel Beam Stand	Break creel beam stand	The beam rotation rate is unstable	The installation of the break adjustment hole is incorrect	PC4	25	0,721	26	Operators must be more careful when installing
Feeding Tension	Feeding roll	Yarn tension is unstable	Broken axle	PC6	27	0,722	27	Replacing broken axle components (the level of damage is severe) and repairing components by welding (the level of damage is light)
Size Box	Immersion roll	Cannot fully soak the yarn	Bearing damaged	PC17	28	0,722	28	Replacing components
Wet Tension	splittingting	Cannot separate wet starched yarns properly and cannot sleep the yarn hairs	Broken axle	PC25	29	0,746	29	Replacing broken axle components (the level of damage is severe) and repairing components by welding (the level of damage is light)
Feeding Tension	Dancing roll	Cannot detect yarn tension	dirty or defective	PC11	30	0,746	30	Check every day or periodically and clean dirty feeding rolls and re-rubber defective or rough feeding rolls
Size Box	Immersion roll	Cannot fully the soak yarn	Broken axle	PC18	31	0,746	31	Replacing broken axle components (the level of damage is severe) and repairing components by welding (the level of damage Splitting
Splitting Tension	Roll tension dry area		Bearing damaged	PC33	32	0,767	32	Replacing components
Feeding Tension	Dancing roll	Cannot detect yarn tension	Broken axle	PC9	33	0,767	33	Replacing broken axle components (the level of damage is severe) and repairing components by welding (the level of damage is light)
Size Box	Immersion roll	Cannot the fully soak yarn	Dirty or defective	PC19	34	0,778	34	Check every day or periodically and clean dirty immersion rolls and repair them with re-rubber for defects or roughness

Feeding Tension	Feeding roll	Yarn tension is unstable	Dirty or defective	PC8	35	0,790	35	Check every day or periodically and clean dirty feeding rolls and repair them with re-rubber for defectsSplittinghness
Splitting Tension	Splitting rod	Cannot conduct yarn	Dirty or defective	PC36	36	0,822	36	Check every day or periodically and clean dirty splitting rods and repair them with re-rubber for defects or roughness
Size Box	Immersion roll	Cannot fully soak the yarn	Hard chrome cracked	PC20	37	0,822	37	Hard chrome repair
Wet Tension	Wet splitting	Cannot separate wet starched yarns properly and cannot sleep the yarn hairs	Rusted chain	PC26	38	0,833	38	Applying grease to rusty chains and replacing components on broken chains
Splitting Tension	Roll tension dry area	Cannot detect yarn tension	Broken axle	PC34	39	0,833	39	Replacing broken axle components (the level of damage is severe) and repairing components by welding (the level of damage is light)
Size Box	Pulley interchange velocity size box	Cannot set beam rotation speed	Less oiling	PC23	40	0,857	40	Controlled application of ISO SAE oil (every three months)
Head Stock	Pulley interchange velocity (PIV) head	Cannot set the tension according to the desired requirements	Less oiling	PC39	41	0,857	41	Controlled application of ISO SAE oil (every three months)

The table above explains that the FMEA approach is applied to a confirmed case of draft quality of a sizing section in the weaving industry, and grey theory is implemented to make comparisons and confirmations. There is no significant difference in the comparison results of the two approaches, only a slight difference in the ranking of 5 potential causes. Conclusions based on the grey theory correspond to the traditional FMEA. This means that the priority ranking results are almost the same. This results can used by related industry to make rational improvement measures on corrective action in the fabric manufacturing process to eliminate or mitigate failure modes with significant risks. As a result, the proposed approach is practical and might offer advice for failure management and decision-making of sizing sections in the weaving industry

5. CONCLUSION

The reliability of a machine can be improved with preventive maintenance. The results of the analysis of the sizing process flow, which causes non-standard draft quality, by applying gray theory to traditional FMEA, found seven potential areas: the creel beam stand area, feeding tension, size box, wet tension, dryer cylinder, splitting tension, headstock. There are 12 potential failure modes and 41 potential causes (PC). There is no significant difference in the top 5 rankings of the RPN assessment between traditional FMEA and the application of gray theory. However, there is a slight difference in ranking on 5 PCs (PC4, PC5, PC13, PC 28, PC 30). The first priority (RPN = 48; GR = 0.588) is in the Creel Beam Stand area in the Break Creel Beam Stand item, which causes the beam to rotate unstable. The potential cause is the beam shaft with the creel unaligned in the beam installation (pneumatic piston not parallel) (PC3). The recommendation is that the operator be more careful when installing the beam into the creel beam holder according to the available SOP and under supervision. The last priority (RPN = 4; GR = 0.857) is in the Head Stock area of the Pulley Interchange Velocity (PIV) Head item, which cannot set the tension according to the desired requirements. The potential cause is less oiling (PC39). The recommendation is to control the oiling of ISO SAE oil every three months. The proposed improvements are hoped to become recommendations and references for priority repairs and maintenance that can be followed up, as well as data to support future research for the Indonesian weaving industry to improve the draft quality. The integration of both approach gives decision makers a practical instrument for evaluating and prioritizing failure possibilities in dynamic decision contexts. In future research, the proposed method can be implemented in other sections in the weaving industry for process improvement and quality product that is a crucial problem. Moreover, other multi-criteria decision making methods, such as fuzzy set theory, can be integrated into risk assessment and management. Its combination with grey theory can be practised in obtaining more realistic analytical results of failure mode risk ranking under various types of uncertainties

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