Occupational Risk Assessment Using the Failure Mode and Effect Analysis (FMEA) Method in the Production Room of Bearing Industry

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Abstract. PT X is an industry engaged in the manufacturing of bearings. This study aims to conduct an occupational risk assessment in the production room of PT X using failure mode and effect analysis (FMEA). The results of risk assessment in 5 working areas in the Production Room resulted in the risk priority number (RPN) value of the raw material storage area were 687, combustion area (30), assembly area (1481), packaging area (296), and the delivery area (432). RPN calculation on FMEA showed that the assembly area has the most significant RPN value, so it was prioritized for risk control measures. The controlling efforts were providing sticks and machine protective covers, replacing damaged button covers, machine operator training, improving standard operating procedures (SOP), and others. Therefore, controlling the risk was expected to reduce the potential risk of a work accident.

Keywords: Bearing, Failure Mode Effect Analysis (FMEA), Production Area, Risk Assessment, Risk Priority Number (RPN)

1 Introduction

Worker health and safety are critical factors that every company must consider to avoid workplace accidents. According to OHSAS 18001 (2007) [1], occupational health and safety is a condition that impacts the health and safety of employees in the workplace. Therefore, every company must implement an occupational health and safety management system that relates to the company's management system under Law No. 13 of 2003 concerning Manpower [2].

A work accident is an unforeseen event at work that can result in damage, illness, or death, resulting in financial losses for both workers and employers [1]. The National Social Security (BPJS TK) reported 147,000 work accident cases in 2018, with 1.75 percent of the instances resulting in death [3]. Workplace accidents can be caused by two causes, according to Pratiwi (2013) [4], dangerous working conditions (unsafe conditions) and unsafe worker activities (unsafe acts). Workplace accidents can have a detrimental influence on employee productivity

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and the cost of compensation and medical bills. Therefore, proper control efforts must ensure that work accidents do not occur again. Identifying potential work accidents within the workplace boundaries is one example of such control initiatives. The FMEA approach is ideal for applying these procedures since it can create a priority scale for each type of work accident [5]. According to Ridley in Sari & Suletra (2017) [6] the FMEA method is used to analyze the cause of a work accident, the probability of a work accident, and how to prevent or handle it.
PT X is an industry that manufactures car and motorcycle bearings with employs over 400 people. Bearings are machine parts that minimize friction between the shaft and other machine parts, limiting relative motion and allowing the shaft to move in the desired direction in vehicles. PT X has implemented the Occupational Health and Safety Management System (SMK3) and obtained the OHSAS 18001 version of 2017 and the Zero Accident certificate in 2009 and 2016. However, there were eight work accidents recorded in the production room throughout the year 2015 to 2019 in PT X. Seeing this, the implementation of SMK3 in PT X, especially in the production room, still needs to be improved. Therefore, it is necessary to identify and conduct the risk assessment in the production room using the Failure Mode and Effect Analysis (FMEA). So that control measures can be recommended to minimize workplace accidents and achieve the target of zero accidents.

2 Research Methodology

This research is qualitative descriptive. The research was conducted by direct observation in the production room of PT X and by conducting interviews with the Environment Health and Safety (EHS) and Sustainability section. In addition, this study also uses secondary data from literature studies based on data released by the company, existing research, and government policies. The Risk Priority Number (RPN) of FMEA was calculated based on the severity, probability (occurrence), and detection (Tabel 1-3). The critical work area was determined based on the RPN value, namely the work area that has the highest RPN value [7]. Furthermore, an analysis of control efforts will be recommended to minimize work accidents in the area.

Tabel 1. Severity Rating

Rating	Criteria	Description
1	Not dangerous	The failure does not cause injury and/or does not cause damage to the machine
2	Very small	The failure does not cause injury and/or machine has minor problems (still manageable by operator)
3	Small	The failure cause very minor injuries and/or the machine may experience minor problems (still manageable by the operator)
4	Very low	The failure cause minor injuries and/or the machine may experience minor problems (still manageable by operator)
5	Low	The failure cause moderate injury and/or machine may experience minor problems (still manageable by operator)
6	Moderate	The failure causes moderate injury and/or machine may experience moderate problem (treated by mechanic)

Rating	Criteria	Description
7	High	The failure cause serious injury and can disrupt the system and require major repairs.
8	Very high	The failure can cause severe or permanent injury and can disrupt the system so seriously that they can stop the system for an indefinite period
9	Dangerous	The failure can cause death (of a person) and serious system damage
10	Very dangerous	The failure can cause death (several individuals) and very serious system damage

Source: Interview result with EHS and Sustainability Section, 2020

Tabel 2. Occurrence Rating

Rating	Criteria	Description
1	Estimated occurrence is very low	The failure almost never happen
2	Low probability	The failure are rare or about once a year
3	Moderate probability of occurrence	The failure happen sometimes or once every 6 months
4		The failure happen sometimes or once every 3 months
5	High probability of occurrence	The failure occurs about once in 1 month
6		The failure occur frequently or about once in 2 weeks
7	The probability occurrence is very high	The failure occur frequently or about once a week
8		Predictable failure occurs or about once in 4 to 5 days
9	Almost unavoidable	Predictable failure occurs or about once in 1 to 2 days
10	Unavoidable	The failure can happen almost any time

Source: Interview result with EHS and Sustainability Section, 2020

Tabel 3. Detection Rating

Rating	Criteria	Description
1	Almost certain	The ability of the tools/control systems used to detect potential failures is almost certain
2	Very high	The ability of the tools/control systems used to detect potential failures is very high
3	High	The ability of the tools/control systems used to detect potential failures is high
4	Middle up	The ability of the tools/control systems used to detect potential failures is middle up
5	Moderate	The ability of the tools/control systems used to detect potential failures is moderate
6	Low	The ability of the tools/control systems used to detect potential failures is low
7	Very low	The ability of the tools/control systems used to detect potential failures is very low
8	Small	The ability of the tools/control systems used to detect potential failures is difficult
9	Very small	The ability of the tools/control systems used to detect potential failures is very difficult
10	No chance of knowing	No device/control system is capable of detecting potential failure

Source: Interview result with EHS and Sustainability Section, 2020

Thus, RPN value could be obtained by following the equation (1) [7].

$$RPN = Severity \times Occurance \times Detection \quad (1)$$

3 Results and Discussion

3.1 Hazard Analysis

The production room is an area that has a high level of mobility because, in this area, there are several activities such as transportation of materials, burning, grinding, washing, packaging and finally bearing delivery to the consumer. Table 4 shows the interview results with EHS and sustainability section regarding the hazard risk identification in the production room of PT X.

Table 4. Hazard Risk Identification in Production Room of PT X

Hazard Risk	Category	
	Unsafe act	***Unsafe Condition***
A pedestrian collision caused by human factors or car damage causes a forklift to collide with an employee.	✓	✓
Products struck the employee because the raw material storage rack was destroyed, causing the goods on the shelf to fall and strike the working employee.		✓
Stumbling is a type of mishap that can cause injury to the sufferer. It occurs when an employee is not paying attention to the road due to a lack of focus or when raw materials are placed untidily.	✓	✓
The non-ergonomic method of transporting/moving products is an accident that occurs when an employee fails to practice proper lifting techniques, resulting in injury.	✓	
Excess heat generated by electromagnetic waves can cause an explosion, triggered by electromagnetic radiation emanating from telephones near the combustion engine.		✓
Taking raw materials that have been burned with their bare hands is an accident because the employee does not utilize personal protective equipment (PPE) such as gloves, resulting in burns.	✓	
Taking a stuck ring with bare hands is an accident caused by workers' attitudes of not wanting to be complicated at work, a lack of knowledge of the necessity of work safety, and employees' lack of thoroughness in not following SOPs.	✓	✓
A finger scraped by a broken machine button cover is an accident caused by the failure to repair damaged tools and personnel who do not use personal protective equipment (PPE) such as gloves while working.		✓
An accident occurs when an employee presses the machine button incorrectly because the employee is less focused and diligent, resulting in a mistake in pressing the button.	✓	
A coolant leak in the engine causes an accident on the floor..		✓

Hazard Risk	Category	
	Unsafe act	*Unsafe Condition*
The failure to use earplugs when entering the assembly room is an accident caused by the detrimental influence of the company's excessive engine noise.	✓	
Employees were delivering chemicals in unsuitable packing cause accidents since the substances can cause poisoning if employees present.	✓	
Considering that PT X has been around for more than ten years and need maintenance, the ceiling of the assembly room is skewed.		✓
The engine electrocuted. This incident was caused because the engine cable was not installed properly, so it could cause the engine to electrocute when touched.		✓
Sharp packaging pieces were exposed to employees, resulting in scratched fingers and ripped employee slacks.	✓	✓
A forklift colliding with a box holding bearings is an accident caused by the driver being weary or exceeding the speed limit.		✓

3.3 Failure Mode and Effect Analysis (FMEA) in the Production Room

The FMEA assessment in the production room was divided into the raw material storage area, combustion area, assembly area, packaging area, and the delivery area. This FMEA aims to determine the critical workstation in the production room based on the most significant RPN. Based on Table 5, several Potential Failure Mode occurred in the raw material storage area. The first potential failure mode was the forklift operator hitting the worker/machine/material caused by the forklift driver being exhausted, the forklift siren being damaged, and pedestrians not walking in the specified path. In this work accident, there was an effect that could cause a pedestrian to hit. This accident caused the death of a person and severe system damage. The second potential failure mode was goods falling from store shelves, resulting in injury to workers and damaged raw materials. This work accident can be caused by the shelf's condition that was damaged or old. The third potential failure mode was that workers fall in the work area, which can cause minor injuries such as bruises on the worker's body. This work accident can be caused because employees ignored the road because they were too focused on chatting/using cellphones, and the placement of raw material boxes was not neat. The last potential failure mode was that the item was not handled ergonomically, which can cause minor injuries such as back pain and sprained hands. The cause of this work accident was that employees did not apply correct lifting techniques. Table 6 mentions that several potential failure modes occur in the combustion area, such as the engine area being exposed to additional heat and workers being exposed to hot materials. Faults/engine areas exposed to additional heat may cause an explosion in a potential engine. This work accident can be caused because employees used cell phones in the burning area. Meanwhile, the potential for errors of workers exposed to hot materials can result in serious injuries such as burns. This work accident was caused by workers not using PPE in the form of gloves while working.

Table 5. FMEA in Raw Material Storage Area

Potential Failure Mode	Potential effect	Potential Causes	Current Process Controls	SEV	OCC	DET	RPN
Forklift operator hits worker/machine/ material	Serious injury, damage to machinery/materials/buildings.	Forklift driver exhausted	Recess	9	2	4	72
		Broken forklift siren	Inspection	9	3	5	135
		Pedestrians disobey the lane	Pedestrian lane, SOP and K3 Signs	9	7	2	126
Items fall from storage shelves	Serious injury, damage to machinery/materials/buildings. Minor injury	Insufficient shelf	Inspection	7	2	5	70
Workers fall in the work area	Minor injury	Unfocused workers	SOP	3	9	2	54
		Laying machines/materials that are not optimal	Safety Patrol and SOP	3	5	2	30
Items are not handled ergonomically	Minor injury	Workers do not consider ergonomics	Recess	5	10	4	200
Total RPN							**687**

Notes: SEV (severity), OCC (Occurance), DET (Detection)

Table 6. FMEA in Combustion Area

Potential Failure Mode	Potential effect	Potential Causes	Current Process Controls	SEV	OCC	DET	RPN
Machine/engine area exposed to additional heat	Explosion	Use of mobile phones near combustion engines	SOPs, warning signs, and Safety Patrols.	10	1	1	10
Workers exposed to hot materials	Serious injury (burn)	Not using full PPE (gloves)	SOP, PPE, and first aid kit	5	2	2	20
Total RPN							**30**

Based on Table 7, potential failure modes occur in the assembly area. The first potential failure mode was the worker getting injured when picking up the ring that gets stuck on the machine, causing machine damage and severe injury. This accident can be caused by a lack of tools availability and the absence of a protective cover of the machine. The second potential failure mode was that workers were injured when operating machines which can cause minor injuries. a broken engine button cover caused this work accident. The third potential failure mode was an error in pressing the engine button, which causes minor injury. this work accident was caused by the layout of the buttons too close together. The fourth potential failure mode was when the worker falls in the work area, which causes minor injury. This work accident was caused by a leak in the engine so that there was an overflow of coolant, the condition of the safety shoes was

inadequate, and the workers did not wear the specified PPE. The potential failure mode of the five workers was exposed to high levels of noise that can cause hearing loss. This work accident was caused because the employee did not comply with the specified regulations, and the engine noise level exceeded 85 dBA. According to the Minister of Health, Regulation Number 70 of 2016 concerning Industrial Occupational Health Standards and Requirements [8], workers might only be exposed to noise frequencies of 85 decibels or less. The sixth mistake was that workers were exposed to chemicals that resulted in the poisoning of workers. This work accident was caused because the worker did not comply with the regulations that the company had determined. The seventh mistake was that the ceiling in the assembly room falls, which results in minor or severe injury. This work accident occurred because the condition of the building was old, and there was no renovation. The eighth mistake of the worker was electrocuted while operating the machine, which could cause electric shock. This work accident was caused by the machine cables not being arranged neatly. The ninth of potential failure mode was non-ergonomic methods of transporting and moving goods. It is due to the employees did not apply correct lifting techniques.

Table 7. FMEA Method in Assembly Area

Potential Failure Mode	Potential effect	Potential Causes	Current Process Controls	SEV	OCC	DET	RPN
Worker injured while picking up ring stuck in machine	Machine breakdown, Serious injury	Worker picks up ring by hand on operating machine	SOP, Safety Patrol and Safety Briefing	7	5	5	175
		No protective cover	SOP and Safety Patrol	7	4	4	112
Workers are injured when operating machines	Minor injury	The engine button cover is broken/damaged	Safety Patrol and PPE	3	3	4	36
Error pressing machine button	Factory operational disruption	Button layout is not optimal	Machine Button Relocation	7	2	4	56
Workers fall in the work area	Minor injury	Coolant spill from a leaking engine	Safety Patrol	4	7	4	112
		Quality safety shoes	Inspection	4	2	5	40
		Workers not wearing PPE	SOP	4	2	2	16
Workers exposed to high levels of noise	Hearing disorders	Workers not wearing PPE	SOP and Safety Patrol	7	10	4	280

Potential Failure Mode	Potential effect	Potential Causes	Current Process Controls	SEV	OCC	DET	RPN
		Engine noise level exceeds 85 dBA	PPE (earplugs)	7	10	1	70
Workers exposed to chemicals	Poisoning	Workers do not comply with SOP	SOP	6	2	2	24
The ceiling in the assembly room is falling	Machine breakdown, Serious injury	The quality of the building is not good	Safety Patrol	8	10	4	320
Workers are electrocuted while operating machinery	Electrocuted	Electrical wiring layout	SOP	5	4	2	40
Items are not handled ergonomically	Minor injury	Workers do not apply ergonomic techniques in handling goods	Recess	5	10	4	200
		Total RPN					**1481**

Based on Table 8, several potential failure occur in the packaging area. The first potential failure was that the item was not handled ergonomically. The second potential failure was that workers fell in the work area, which can cause minor injuries. This work accident can be caused because workers did not too focused on chatting or using cellphones when walking. The third potential failure was that workers were scratched by sharp parts of the bearing packaging, which can cause minor injuries. This work accident was caused because the employee did not use the specified PPE.

Table 8. FMEA in Packaging Area

Potential Failure Mode	Potential effect	Potential Causes	Current Process Controls	SEV	OCC	DET	RPN
Items are not handled ergonomically	Minor injury	Workers do not apply ergonomic techniques in handling goods	Recess	5	10	4	200
Workers fall in the work area	Minor injury	Unfocused workers	SOP	3	10	2	60
Workers scratched by sharp parts of bearing packaging	Minor injury	Not using PPE	PPE, SOP, and first aid kit	3	6	2	36

Potential Failure Mode	Potential effect	Potential Causes	Current Process Controls	SEV	OCC	DET	RPN
Total RPN							**296**

Table 9. FMEA Table in Delivery Area

Potential Failure Mode	Potential effect	Potential Causes	Current Process Controls	SEV	OCC	DET	RPN
Forklift operator hits worker/machine/ material	Serious injury, damage to machinery /materials/ building	Forklift driver exhausted	Recess	8	2	4	64
		Another worker who doesn't have a driver's license tries to drive a forklift	Safety Patrol	8	3	4	96
		Forklift operator driving a forklift not at the specified speed	SOP	8	2	2	32
Workers exposed to sharp parts of the box bearing	Minor injury	Workers do not pay attention to the road because they are too focused on	SOP	1	10	2	20
		chatting/use cell phone					
		Placement of the box bearing does not match what has been determined	SOP and Safety Patrol	1	5	4	20
Workers are injured when moving or transporting goods	Minor injury	Workers do not apply ergonomic techniques in handling goods	Recess	5	10	4	200
Total RPN							**432**

While on the Table 9, several potential failure occur in the delivery area. The first potential failure was the forklift operator hitting the worker/machine/material, which can cause severe injury and damage to the box bearing that was ready to be shipped. This work accident can be caused because the forklift driver was exhausted, workers who did not have a driver's license tried to drive a forklift, and the forklift operator did not drive at the company's speed recommendation. The second potential failure was that workers were exposed to sensitive parts of the box bearing, resulting in minor injuries. This work accident was caused because employees ignored the road, and the placement of the box bearing was not as determined. The third potential failure was that workers were injured when moving or transporting goods, resulting in minor injuries.

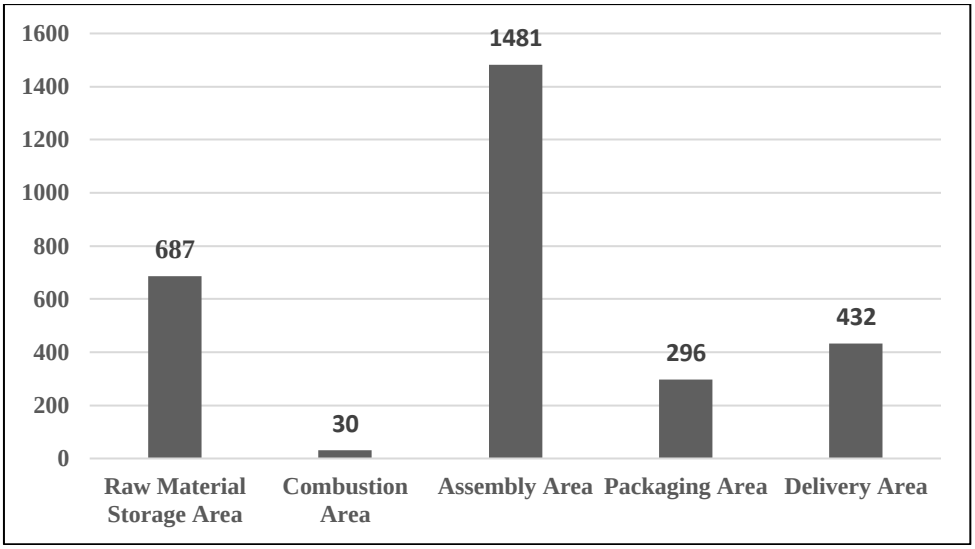

Fig 2. Comparison of total RPN value in all areas

Figure 2 shows that the assembly area had the highest RPN of 1481. The assembly area was a selected work area that was prioritized to be controlled because it had the most significant RPN. In this area, nine work accidents have occurred. There were suggestions to reduce workplace accidents in the assembly area by preparing backup tools in the form of sticks and protective covers on the machine so that work accidents do not occur when picking up the stuck ring. Replace the damaged machine button cover so that there are no sharp parts from the engine button cover that can cause injury to workers [9]. Provide machine operators with regular training and socializing related to work safety for three months so that they do not press the machine button incorrectly. Additionally, employing anti-slip coatings, having backups, and regularly inspecting safety shoes can help maintain a comfortable and safe workplace environment [10]. In reducing work accidents caused by high engine noise, socialization and training related to personal protective equipment (PPE) can be carried out. Socialization and training related to PPE can create awareness regarding the use of PPE to avoid work accidents [11]. The solution that can be done to reduce work accidents due to poisoning is to disseminate clear work procedures related to the containment or use of chemicals. In addition, to reduce work accidents due to falling assembly room ceilings, it can be done by replacing the ceiling with a new one. According to the Minister of Public Works Regulation Number 24 of 2008 concerning Guidelines for Building Care and Maintenance [12], it is stated that the ceiling on a building may be damaged if it has been used for approximately ten years. In addition, according to Rahmah (2017) [13], making special boxes to store cables located in areas that are not passed by employees or placed on walls can reduce the risk of work accidents due to electric shock. The final solution that can reduce work accidents due to transportation of non-ergonomic goods can be done by educating workers regarding ergonomics. Education related to ergonomics has been shown to reduce low back pain complaints [14]. Table 10 shows the recommended action to tackle the potential failure in Assembly Area.

Table 10. Recommended Action as a Risk Control Measure in the Assembly Area

Potential Failure Mode	Recommended Action
Worker injured while picking up ring stuck in machine	Provide tools (sticks) to take the ring, install the engine protective cover, and install K3 Signs.
Workers are injured when operating machines	Replace the damaged engine button cover.
Error pressing the engine button	Conduct regular training for machine operators and install OHS Signs.
Workers fall in the work area	Install anti-slip on the floor.
	Provide spare safety shoes and check worker safety shoes
Workers exposed to high levels of noise	Conduct socialization and training related to personal protective equipment
Workers exposed to chemicals	Develop clear work procedures related to the containment & use of chemicals in the assembly room and install K3 Signs.
The ceiling in the assembly room is falling	Replace the damaged ceiling with a new ceiling.
Workers are electrocuted while operating machinery	Arrange the laying of electrical cables specifically.
Items are not handled ergonomically	Organizing regular ergonomics training for workers and installing OHS Signs related to ergonomics.

4 Conclusion

Risk assessment using the FMEA method in the production room of PT X was conducted. The raw material storage area gets a total RPN value of 687. In the combustion area it gets a total RPN value of 30. The assembly area gets a total RPN value of 1481. In the packaging area it gets a total RPN value of 296 and in the delivery area it gets the total RPN value is 432. Based on the total RPN value obtained, it is concluded that the work area that has the highest RPN value is the assembly area which has an RPN value of 1481. Recommendations for control actions that can be taken to minimize the work accidents in the assembly area were to provide more spare tools (sticks) and machine protective covers, replace damaged machine button covers, provide retraining to machine operators, use anti-slip floor coatings, provide spare safety shoes for employees or guests, make socialization and training programs related to personal protective equipment, make clear work procedures related to the containment/use for chemicals, replace damaged ceilings with new ones, manufacture special boxes for storing cables located in areas that are not passed by employees or placed on walls, and finally providing training to workers regarding ergonomics.

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