Work Accident Risk Assessment in Hot Rolled Coil Production with The Failure Mode, Effect and Criticality Analysis (FMECA) Method at PT XYZ

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Abstract
In HRC production at PT XYZ which is carried out continuously to pursue the production target will be in effect on the HRC production component with the risk management methods is Failure Mode, Effect and Criticality Analysis (FMECA). The purpose of this study is to identify the source of potential failure in HRC production, analyze the RPN value, and determine control recommendations. Data collection methods are carried out by means of direct observation of HRC production, interviews, and literature studies. The results on the risk assessment by the FMECA method are leakage and operational failure of the burner device with a RPN value of 420, the Refractory Brick Furnace crack of 324, the scale piece bounced off the 294 reservoir, the oil leak on the flat pass, the work roll, and the backup roll of 252 , damage to the roller table machine is 240, operational failure on the Looper engine of 240, and the failure of the HRC product binding manually is 240. Risk control in HRC production is the use of flame rod indicators, ultraviolet sensors, ultrasonic tests, installation of slab pieces cover, thermal infrared camera, LOTO use, quadratic linear inverse system or predictive control, distance guard, and periodic maintenance.

Keywords: Risk management, FMECA Method, Risk assessment, HRC Production, Risk control

Introduction

Steel is a ferrous metal consisting of a composition of materials such as iron ore, coal, flux, and recycled steel. Steel will be processed and shaped according to production needs such as billets, blooms and slab (Wang, G, 2016). Steel companies as producers of several company sectors such as infrastructure, automotive and shipping. The availability of construction steel material in infrastructure development in Indonesia is still relatively low at 84 kg/capita compared to other countries (Sekretariat Direktorat Jenderal, 2018). The development of automotive companies over the past 10 years has utilized steel as much as 30% in components such as body and chassis vehicle. In 2020-2024, the condition of steel companies still does not meet the needs of ship manufacturers of 20,835.37 tons (Saputro, et al, 2021). Work accidents in Indonesia have increased from 2020-2022 by 265,334 thousand cases of work accidents (Mediana, 2023). Based on data on cases of work accidents and occupational diseases in 2019-2021 in the basic and chemical industries, there were around 80,607 cases with a percentage of around 12.1% (Yuli, et al, 2022). One of the work accidents in a steel company, when slab the heat escaping from the line then damages production equipment and workers are exposed to level 1 burns (Fajri, 2019).

Steel companies need equipment and technology in the production process so that the products produced are of quality and efficient. An integrated steel producer in Indonesia is PT XYZ with a factory called Hot Strip Mill (HSM). HSM is a slab production site into hot rolled coil and plate with a capacity of 2.4 million tons per year. Hot Rolled Coil (HRC) is a steel product in the form of a roll while the plate is in the form of a sheet (PT XYZ, 2021). The HSM plant has five stages of production, namely reheating furnace, sizing press, roughing mill, finishing mill, and down coiler. PT XYZ has used a risk assessment method, namely: Hazard Identification, Risk Assessment and Determining Control (HIRADC). The document addresses potential hazards and risks when facilities and equipment are under maintenance conditions. The use of the FMECA method will assess the potential hazards and risks posed by equipment components during HRC production.

Based on ISO 31010, FMECA method strongly applicable for risk identification, analysis, and evaluation compared to other methods. The results of the risk assessment from the FMECA method are in the form of values Risk Priority Number (RPN). The value is obtained from the result of multiplication between failure rate, severity, and problem detection rate (Hollcroft, et al, 2016). The use of FMECA methods has advantages in identifying risks such as revealing safety issues in an area, focusing on key areas of the production process and others (Hollcroft, et al, 2016). This research was conducted to identify potential sources of failure that can occur in production. Hot Rolled Coil at PT XYZ, analyze Risk priority number on production Hot Rolled Coil, and determine control recommendations that can be put in place to reduce production failures.

Occupational Safety and Health (K3) are all activities to guarantee and protect the safety and health of workers through efforts to prevent work accidents and work-related diseases (Government of Indonesia, 2012). Work accidents caused by human actions that are not in accordance with safety are called unsafe human actions. In addition, accidents can be caused by unsafe environmental conditions called unsafe conditions. In assessing risk management in a company, several K3 risk assessment methods can be used, one of these methods is Failure Mode, Effect and Criticality Analysis (FMECA). This method will analyze the potential hazards and risks posed by a process, system, and tool. In addition, the use of the FMECA method can be a qualitative or semi-quantitative method that describes the process of potential failure and its causes (Hollcroft, et al, 2016). Each failure will be assessed using parameter criteria components, namely severity criteria, the possibility of failure occurring, control design (detection) and criticality level.

Literature Review

Table 1. Failure Mode Severity

Severity	Criterion	Rank
Losing a life or changing an individual's life	Death of several individuals (mass)	10
	Death of an individual (a person)	9
	Needs serious treatment and creates permanent disability	8
Have a great impact on the individual so that they no longer participate in the activity	Treated for more than 12 hours, with blood vessel rupture wounds, severe memory loss, heavy losses, etc	7
	Treated for more than 12 hours, fractures, bone shifts, frostbite, burns, difficulty breathing and temporary memory forgetfulness, falls/slips	6
The impact received is moderate (individuals only 1 to 2 days do not participate in the activity)	Sprains, minor cracks/fractures, cramps, or spasms	5
	Minor burns, scratches, frosnips	4
The impact received is small (individuals still participate in the activity)	Blisters, heatstrokes, mild sprains, minor slips or slips	3
	Blisters, heatstrokes, mild sprains, minor slips or slips	2
No impact (individuals do not get a pronounced impact)	Blisters, heatstrokes, mild sprains, minor slips or slips	1

Source: (Priest, 2005)

Table 2. Failure Mode Occurrence

Occurrence	Frequency	Rank
Very high: Failure is almost uncontrollable	≥150 out of 1,500,000	10
	100 out of 1,500,000	9
Tall: Repeated failures	70 out of 1,500,000	8
	50 out of 1,500,000	7
Keep: Occasional failures	20 out of 1,500,000	6
	10 out of 1,500,000	5
	8 out of 1,500,000	4
Low: Relatively few failures	5 out of 1,500,000	3
	2 out of 1,500,000	2
Smallest: Failure is unlikely	1 in 1,500,000	1

Source: (International Standardization Organization, 2006)

Table 3. Failure Mode Detection

Detection	**Criterion**	**Rank**
Almost impossible	No controls in detecting potential failures	10
Very small	Very few controls in detecting potential failures	9
Small	Little control but potential failure	8
Very low	There is control but very low capability	7
Low	There is control but low capability	6
Keep	There is control but moderate ability	5
Quite high	There is control but enough ability	4
Tall	There is a control that has high capabilities	3
Very high	There is a control that has very high capabilities	2
Almost certainly	Control can almost certainly detect potential failures	1

Source: (International Standardization Organization, 2006)

Table 4. Category Risk Priority Number (RPN)

RPN value	**Categories Criticality**
501 – 1000	Tall
201 – 500	Keep
1 - 200	Low

Source:.(Alijoyo, et al, 2020)

The FMECA method can be applied to potential failures of people, equipment, systems and procedures. In manufacturing companies, the use of the FMECA method has advantages in identifying potential failures. Following are the advantages of using the FMECA method, namely logical model in evaluating the probability or failure of operational conditions, provide guidance to the document, minimizing expensive maintenance costs, etc (International Standardization Organization, 2006).

Material and Method

Location and Time of Research

This research will be conducted at PT XYZ which is in an integrated industrial area with a land area of 3,250 Ha. The location is a research location because PT XYZ is a steel producer company in Indonesia. The research will be carried out for approximately 6 months starting in February 2023 until August 2023.

Forms of Research and Data Collection Methods

This research will identify and analyze the components of HRC production facilities and equipment. The data needed in conducting this research are production activity data, equipment usage period data, production facility component data, and production equipment data. This form of research is carried out with semi-quantitative research methods supported by direct observation data and company documents. This method explains the definition of the problem from a numerical number scale to determine the weighting of the problem (Hollcroft, et al, 2016). The quality of research results will depend on research instruments and data collection. The quality of the instrument will test the truth based on data collection such as interviews, observations, and knowledge of a researcher. Observation is carried out direct observation of the object of study to get a point of view of a phenomenon or its effects. This observation can be done by documenting an object so that it can examine a work process of a production (Kusumastuti, et al, 2019). Observations were made on the HRC production process at PT XYZ's HSM factory. In the FMECA method analysis, the determination of risk values uses several sources such as research journals and books against the criteria severity, occurrence, and detection. This is tailored to the needs of research in risk identification, analysis, and evaluation to minimize the presence of work accidents.

The interview was conducted by means of direct discussion with the person in charge of the HRC production process unit of PT XYZ. The interview will consist of four categories of questions such as introductory questions, transition questions, key questions, and closing questions (Castillo-Montoya, M, 2016). Interview sampling was carried out on a small scale with the number of speakers taken around 1 to 10 people (Hansen, S, 2020). Researchers can increase and decrease the number of resource persons if the information is in accordance with needs (Heryana, 2019). Researchers select resource persons based on several criteria such as education, experience in work, and good information (Van Manen, M, 2014). In addition, employee work experience in the range of 1 to 2 years is still not optimal in knowing the work that affects work results (Suwarno, R, 2019). However, undergraduate graduates can be said to have experience working in accordance with their majors for at least 2 years while baccalaureate graduates have at least 4 years (Peraturan Menteri, 1992). Literature study is a technique in understanding theories or procedures that are in accordance with risk management and HRC production processes at PT XYZ. Official company documents such as risk management data, HRC production flow, and production equipment components.

Data Analysis Method

In analyzing worksheets there are several steps in analyzing potential failures with the FMECA method. First, identification of production units in five stages was carried out at PT XYZ HSM factory. Second, identify the mode of failure at each stage of HRC production. Third, analysis of the impact of failure derived from the results of identifying failure modes. All potential failures will have an impact that must be considered against the rest of the process (Husen, 2021). Fourth, the determination of the value of criteria such as severity, occurrence, and detection which refers to

the Analysis and Procedure of the FMECA Method (International
tandardization Organization, 2006). Fifth, the calculation of the total RPN value based on the multiplication of numbers on the criterion value is then determined by the results of the criticality level. The level of criticality is divided into three categories, namely low, medium, and high (Alijoyo, et al, 2020). Sixth, determination of control recommendations that refer to the control hierarchy, namely elimination, substitution, engineering control, administration, and PPE (Masjuli, et al, 2019).

Result and Discussion Overview of Production

In HRC production at PT XYZ is a factory called HSM to produce HRC and plate products. The HSM plant will have the main raw material in production in the form of steel slabs. First, the Reheating Furnace (RF) unit is a slab raw material heating unit. PT XYZ has two RF units using natural gas fuel type and walking beam type along with combustion equipment. combustion time is about 1-3 hour and the temperature is about 1200°C. Second, the Sizing Press (SP) unit is a unit that reduces the thickness by 280 mm and a width of about 650-2,300 mm on the slab and is pressed on each side using a sizing pass tool. The tool is driven by high- pressure hydraulics.

Third, the Roughing Mill (RM) unit is an initial thickness reduction unit for the slab by rotating 5-9 times using 2 work roll tools (up and down). The slab will change to Transfer Bar (T-Bar) size. Slabs or T- bars that have been processed in RM units will go through a tool, namely crop shear. Fourth, the Mill Finishing unit (FM) is a final thickness reduction unit. The HSM plant uses six FM units to reduce the thickness of strips with different types of thickness reduction. The FM unit has a looper to minimize voltage on the strip. Fifth, Down Coiler (DC) unit is a unit for rolling sheet strips in the form of coil. DC units used as many as two pieces and strips in cold conditions will enter through the top and bottom hydraulic mechanisms on the pinch roller tool. The tool aims for the strip head to follow the wrapper roll path.

Identification of Risk Reheating Furnace Unit

In the early stages of making HRC in the HSM plant, the furnace reheating unit. This unit will expand the main raw material in the form of slabs with natural gas fuel sources. The main components in the reheating furnace unit are the refractory brick furnace and burner. These components can withstand and increase the temperature in the slab expansion process.

Table 5. Failure Mode Results and Unit Failure Impact Reheating Furnace

Activities in Production	Sort Number	Failure Mode	Impact of Failure	Tool Image
1. Reheating Furnace	1.1	The rotation of the roller table machine is too fast	The slab will bounce and hit employees around the production line	
	1.2	Damage to the roller table machine	Employees have the potential to be entangled in roller table machines	
	1.3	Wear on side guide tools	Steel slabs will concern and potentially expose employees around the production line	
	1.4	Cracking refractory brick furnace cannot withstand high temperature	The furnace wall will experience expansion and potentially experience an	

			explosion	
	1.5	Leakage and operational failure of the burner tool	The burner can cause an explosion in the furnace reheating area	

At the beginning slab inserted into the unit furnace reheating will be distributed by machine roller table that works continuously. The impact that occurs when the machine roller table spinning rapidly can result in scale (crust) and slab will bounce around the production line. The composition of the oxides formed can affect the properties of the crust (Kenedy, et al, 2012). Speed on the engine roller table ranges from 0.5-4 m/s (Airblast Group, 2015). Movement instability roller and slab during production hot rolled coil continuously at high speeds will result in serious repercussions. The impact resulted in slab will experience indentations and hit the sides side guide so that the slab will reverse as well as continuous collision (Aoh, et al, 2019). Engine breakdown roller table can occur because of rotary coupling, electric motors, and roll (Anthony, 2016). When the machine roller table malfunctions and there are employees who check in operating and maintenance conditions have the potential to be entangled in the machine.

The side guide aims to hold the tip or tail slab and streamline the distribution, entry and exit process slab to the later units (Washikita, et al, 2016). If slab has curvature and rubs against side guide, slab will bend with one side with side guide so that slab will go off the production line (Hsu, H and Aoh, J., 2019). High temperature in the room rehating furnace will lead to shrinkage of thickness refractory brick (Chaudhary, et al, 2015). Failures and cracks refractory brick if not controlled effectively, refractory brick will explode explosively (Morgan, 2017). This combustion will be affected by the speed of motion slab, temperature, and tool distance burner (Liu, et al, 2020). Gas pipeline leaks and combustion equipment can occur due to corrosion or cracks. If this happens, there can be potential for fire and explosion in the unit furnace reheating (Setiawan, et al, 2018). Exposure to high temperatures when the closing door is open ranges from 550°C due to slab coming out subjected to steel expansion. Employees around the area can be assured of exposure to high temperatures and heat stress.

Identification of Risk Sizing Press Unit

The second stage is the sizing press unit, this unit will reduce the thickness and width on each side of the slab. The main component in the sizing press unit is the sizing pass, the component will press and clog the slab with high pressure with a hydraulic system.

Table 6. Failure Mode Results and Unit Failure Impact Sizing Press

Activities in Production	**Sort Number**	**Failure mode**	**Impact of failure**	**Tool Image**
2. Sizing Press	2.1	The rotation of the roller table machine is too fast	The slab will bounce and hit employees around the production line	
	2.2	Damage to the roller table machine	Employees have the potential to be entangled in roller table machines	
	2.3	Wear on side guide tools	Steel slabs will concern and potentially expose employees around the production line	

On the machine sizing pass, oil on the engine to facilitate the engine drive on roll. If the oil pressure in the driving engine is too high, it will cause potential danger. There is damage to the engine caused by poor operation and high engine pressure, resulting in engine failure and causing oil leaks (Santiko, 2019). Oil leaks can cause fires due to lighter sources and flammable materials (International Labour Organization, 2018).

Identification of Risk Roughing Mill Unit

The third stage is the roughing mill unit, this slab unit will be roughly reduced in initial thickness. In addition, the timing and speed of slab distribution will be determined by the operators working in the unit. The slab will be rotated with work roll and back up roll 5-9 times. The slab that has been reduced will be cut at each end using the crop shear tool.

Table 7. Failure Mode Results and Unit Failure Impact Roughing Mill

Activities in Production	**Sort Number**	**Failure mode**	**Impact of failure**	**Tool Image**
3. Roughing Mill	3.1	The rotation of the roller table machine is too fast	The slab will bounce and hit employees around the production line	
	3.2	Damage to the roller table machine	Employees have the potential to be entangled in roller table machines	
	3.3	Wear on side guide tools	Steel slabs will concern and potentially expose employees around the production line	
	3.4	Roller cracking on work roll machine and back up roll	The roller machine will cause an electric short circuit	
	3.5	Oil leakage in work roll and back up roll machines	Oil spills can cause employee slips and fires	
	3.6	Slab pieces and bounced scales from crop shear machine reservoirs	Scale on the rest of the slab cut has the potential to burn employees	

On the same process slab will always be distributed with machines roller table. Back up roll and work roll are tools for carrying out rough thinning in the unit roughing mill. Slab will be rolled many times on Back up roll with a high speed of about 3-40000 kN (Kucsera and Beres, 2015). This may result in cracks in Back up roll and work roll (Hsu and Aoh, 2019). Usage and damage to the roller machine will have a potential danger in the form of an electrical short circuit. This will affect operational failure and interfere with the performance of the machine.

On the machine back up roll and work roll there is a high-pressure oil chamber adapted to the pressure distribution of the coils (Wang, et al, 2012). Oil on the engine to facilitate the engine drive on roll. If the oil pressure in the driving engine is too high, it will cause potential danger. Oil leaks will threaten the safety of employees (Putra, 2021). There is damage to the engine caused by poor operation and high engine pressure, resulting in engine failure and causing oil leakage (Santiko, 2019). Oil leaks can cause fires due to lighter sources and flammable materials (International Labour Organization, 2018). Such machines are located between the units roughing mill and finishing mill. HRC products have an ambient temperature of 550°C
which depends on thickness coil (Lestari, et al, 2018). Shelters with open have potential hazards such as bouncing slab or scale resulting in burns to employees who are inspecting equipment.

Identification of Risk Finishing Mill Unit

The fourth stage is the finishing mill unit, a slab that has been roughly reduced in thickness and width in the roughing mill unit. The strips will be reduced back to specification and custom order on six work roll and back up roll tools. Each tool in the finishing mill will have a different type of thickness. In addition, each side of the work roll and back up roll tool will have a tool that reduces the tension of the strip called a looper.

Table 8. Failure Mode Results and Unit Failure Impact Finishing Mill

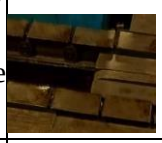
Activities in Production	Sort Number	Failure mode	Impact of failure	Tool Image
4. Finishing Mill	4.1	The rotation of the roller table machine is too fast	The slab will bounce and hit employees around the production line	
	4.2	Damage to the roller table machine	Employees have the potential to be entangled in roller table machines	
	4.3	Wear on side guide tools	Steel slabs will concern and potentially expose employees around the production line	
	4.4	Roller cracking on work roll machine and back up roll	The roller machine will cause an electric short circuit	
	4.5	Oil leakage in work roll and back up roll machines	Oil spills can cause employee slips and fires	
	4.6	Operational failure on looper machine	Slabs have the potential to go off the production line and cause burns	

Looper located at the end of the stand finishing mill which results in a constant line voltage. The existence of this machine aims to prevent depletion strip which is caused by high voltage. In addition, high voltage will have an impact on disconnection strip of the unit (Gaber, et al, 2022). The existence of strip which is interrupted at the time of production in the unit finishing mill, strip will exit the unit and potentially hit the employee. Operation looper using electrical systems and equipment that have the potential danger of operational failure. The electrical system has a high influence so that electric current needs to be maintained to continue to function properly. If the electrical system experiences an operational failure, it will have an impact on looper (Yarandi, et al, 2023). HRC products have an ambient temperature of 550°C which depends on thickness coil (Lestari, et al, 2018).

Identification of Risk Down Coiler Unit

The last stage in the manufacture of HRC at the HSM plant is the down coiler unit. Strips that have gone through the final reduction in the mill finishing unit will be distributed to the down coiler unit. This unit will roll the strip sheet into a coil and be coded and controlled back on the surface of the coil. The workflow of the down coiler unit, the strip sheet will go through the switch gate to enter the hydraulic centering cylinder tool. Furthermore, the coil will be glued with stainless steel bands mechanically or manually.

Table 9. Failure Mode Results and Unit Failure Impact Down Coiler

Activities in Production	Sort Number	Failure Mode	Impact of Failure	Tool Image
5. Down Coiler	5.1	The rotation of the roller table machine is too fast	The slab will bounce and hit employees around the production line	
	5.2	Damage to the roller table machine	Employees have the potential to be entangled in roller table machines	
	5.3	Wear on side guide tools	Steel slabs will concern and potentially expose employees around the production line	
	5.4	The switch gate machine cannot open	The strip will go off track and potentially fire	
	5.5	Damage to the cylinder traveling coil car engine	HRC products will be detached from potentially fire coils	
	5.6	Cylinder hydraulic centering engine	The strip will damage tool components as well as cause a fire	
	5.7	Short circuits and cavities in chain transport machines	Employees are squeezed by the transport chain and electric current has the potential to cause fires	
	5.8	Manual HRC product binding failure	Employees have potential heat exposure and burns	

On the same process strip will always be distributed with machines roller table. Machine switch gate serves to give direction to the end strip log in to mandrel coiler. In addition, this machine can change

direction strip heading to another unit with a very short time (SMS Siemag, 2019). On operation in the unit down coiler using electrical systems and equipment that have the potential danger of operational failure. If the electrical system experiences an operational failure, it will have an impact on the system down coiler (Yarandi, et al, 2023). The potential of existence strip who experienced operational failures in switch gate machine that is to damage production components that cause fire impacts.

On the machine cylinder hydraulic centering and cylinder travelling coil car is a component of the tool in the unit down coiler. This machine works to maintain stability coil at the time of strip rolled with the help of two tongs and a hydraulic system so that stability occurs in the machine. Any damage to the engine caused by poor operation and high engine pressure will result in engine failure and cause oil leakage (Santiko, 2019). Oil leaks can cause fires due to lighter sources and flammable materials (International Labour Organization, 2018)

After strip exit the unit down coiler, will be distributed by machine chain transport. The machine is driven by a hydraulic motor that carries coil with a maximum speed of about 0.8 m/s and a length of about 27 m (Degneer, 2000). Hydraulic machines driven by electricity have the potential for danger when experiencing an electrical short circuit. Potential hazards arising from the presence of electric currents such as shocks, fires, and explosions. Such potential can threaten people and property (Kamuikhar, et al, 2022). In addition, the cause of the fire is the presence of a source of lighter and flammable materials (International Labour Organization, 2018). Bindings can be categorized into two types, namely mechanical and manual fastening. The existence of a manual bonding process can result in employees potentially exposure to heat and burns. The fastening is carried out at close range and is in a dangerous area. Heat stress on steel production is in the area down coiler and furnace reheating. HRC products have an ambient temperature of 550°C which depends on thickness Coil (Lestari, et al, 2018). In the production of HRC, employees need to maintain body condition due to increased overheating.(Fahed, et al, 2018)

Assessment of HRC Production Risk Assessment

After identifying the mode of failure and the impact of failure, a risk level analysis is carried out. The level of risk will refer to three criteria, namely the severity (severity) which will affect the possibility of failure (occurence) and control design (detection). The level of these criteria has different values and meanings so that it will get a determination of the level of criticality.

Table 10. HRC Production Risk Level Assessment

Sort Number	Severity	Occurrence	Existing Control	Detection	**Risk Priority Number (RPN)**	Category
1.1	6	5	Safety factors and safety line	5	**150**	Low
1.2	8	5	Standard Operating Procedure (SOP) Document	6	**240**	Medium
1.3	8	5	Standard Operating Procedure (SOP) Document	5	**200**	Low

1.4	9	6	Standard Operating Procedure (SOP) document and visual check	6	**324**	Medium
1.5	10	7	Human machine interface	6	**420**	Medium
1.6	3	4	Standard Operating Procedure (SOP) Document	6	**72**	Low
2.1	6	5	Safety factors and safety line	5	**150**	Low
2.2	8	5	Standard Operating Procedure (SOP) Document	6	**240**	Medium
2.3	8	5	Standard Operating Procedure (SOP) Document	5	**200**	Low
2.4	7	6	Visual check	6	**252**	Medium
3.1	6	5	Safety factors and safety line	5	**150**	Low
3.2	8	5	Standard Operating Procedure (SOP) Document	6	**240**	Medium
3.3	8	5	Standard Operating Procedure (SOP) Document	5	**200**	Low
3.4	5	4	Standard Operating Procedure (SOP) Document	6	**120**	Low
3.5	7	6	Visual check	6	**252**	Medium
3.6	7	7	Standard Operating Procedure (SOP) Document	6	**294**	Medium

4.1	6	5	Safety factors and safety line	5	**150**	Low
Sort Number	**Severity**	**Occurrence**	**Existing Control**	**Detection**	**Risk Priority Number (RPN)**	**Category**
4.2	8	5	Standard Operating Procedure (SOP) Document	6	240	Medium
4.3	8	5	Standard Operating Procedure (SOP) Document	5	200	Low
4.4	5	4	Standard Operating Procedure (SOP) Document	6	120	Low
4.5	7	6	Visual check	6	252	Medium
4.6	8	6	Safety factors	5	240	Medium
5.1	6	5	Safety factors and safety line	5	150	Low
5.2	8	5	Standard Operating Procedure (SOP) Document	6	240	Medium
5.3	8	5	Standard Operating Procedure (SOP) Document	5	200	Low
5.4	4	4	Strip barrier	3	48	Low
5.5	7	5	Standard Operating Procedure (SOP) Document	5	175	Low
5.6	7	5	Standard Operating Procedure (SOP) Document	5	175	Low
5.7	7	4	Standard Operating Procedure (SOP) Document	5	140	Low
5.8	8	5	Standard Operating Procedure (SOP) Document	6	240	Medium

The existing control at PT XYZ in HRC production consists of human machine interface, safety factor and safety line, visual check, barrier strip, and SOP documents. First, the risk assessment on the buner in the reheating furnace unit which has a total criticality level of RPN value from the assessment results of 420 with a medium category. Second, refractory brick cracking in the reheating furnace unit has an explosive explosion with a total criticality level of RPN value of 324 in the medium category. Third, a crop shear machine to cut each slab if the cut and scale are bounced from the reservoir with a total criticality level of RPN value of 294 in the medium category. Fourth, oil leakage in roller engines driven by hydraulic systems with a total criticality level of RPN value of 252 in the medium category. Fifth, damage to the roller table machine which has the potential for employees to be entangled during maintenance conditions with a total criticality level of RPN value of 240 with a medium category. Sixth, the looper tool has the potential that the strip is not strong enough to withstand the voltage will be cut off and result in exit from the production line and burns with a total criticality level of RPN value of 240 in the medium category. Seventh, Manual bonding is carried out if mechanical bonding does not work in the down

coiler unit which has the potential to be exposed to heat exposure and burns with a total criticality level of RPN value of 240 with a medium category.

Risk Control and Assessment Return HRC Production

The existence of risk assessment and determination of criticality level categories can facilitate risk control. This determination is to reduce the potential for work accidents caused by equipment components and HRC production conditions at the HSM Plant. Risk control will refer to the control hierarchy namely elimination, substitution, engineering control, administration, and personal protective equipment. After the control recommendations are made, they will be reassessed at all three levels to reduce the impact of risks arising from each tool.

Table 11. Control and Risk Assessment of HRC Production Return

Sort Number	Control recommendations	Severity	Occurrence	Detection	Risk Priority Number (RPN)	Category
1.1	Eng: Added safety factors roller table speed Adm: Pedestrian update between employee distance to production line	4	2	2	16	Low
1.2	Eng: Addition of machine damage indicator tool Adm: Update SOP, LOTO, and information board when machine is under maintenance	3	2	1	6	Low
1.3	Eng: Added side guide depletion indicator Adm: Pedestrian update between employee distance to production line	4	3	2	24	Low
1.4	Eng: Use of crack indicator device in reheating furnace Adm: Inspect and update SOPs on refractory bricks	5	2	2	20	Low
1.5	Eng: Use of failure indicator tool on burner tool Adm: Periodic maintenance and inspection of burner tools	4	3	3	36	Low
1.6	Eng: Addition of wind blowers around the furnace reheating area Adm: Periodic testing and checking of pulley system equipment	2	1	3	6	Low
2.1	Eng: Added safety factors roller table speed Adm: Update of pedestrian SOP between employee distance to	4	2	2	16	Low

	production line					
2.2	Eng: Addition of machine damage indicator tool Adm: Update SOP, LOTO, and information board when machine is under maintenance	3	2	1	6	Low
2.3	Eng: Added side guide depletion indicator Adm: Update of pedestrian SOP between employee distance to production line	4	3	2	24	Low

Based on the RPN value with the medium category there are seven failures, control recommendations are made due to equipment failures and conditions in HRC production at PT XYZ. Risk control recommendations refer to the control hierarchy of elimination, substitution, engineering control, administration, and PPE.

1. In leakage and operational failure, buner equipment can use flame rod indicators or ultraviolet sensors (Gallagher and Martin, 2014). Maintenance and inspection of burners and safety valves approximately once a month (Samudro, 2022). Operators who maintain the stability of the burner equipment monitor the unit according to procedures and turn off all equipment if it experiences leaks and operational failures (Ministerial Regulation, 2016).
2. Refractory brick cracking in furnace reheating units can be used in ultrasonic tests (Ministerial Regulation, 2016). Maintenance and inspection of refractory bricks about once every six months.
3. The slab slab on the crop shear machine can be installed with a cover or barrier to the slab end piece and is equipped with automatic stopping devices and protective equipment (Ministerial Regulation, 2016).
4. Oil leakage in the engine sizing pass, backup roll, and work roll can be used as a thermal infrared camera tool (Fahimipirehgalin, et al, 2020). Equipment or lifting platforms from horizontal centrifugal machines in the form of pipes or other forms must be closed and provided with protective equipment with safety (Ministerial Regulation, 2016). Inspection and maintenance of rolling machines once a week to improve tool performance (Gani and Lokajaya, 2023).
5. Damage to the roller table machine can use a thermal camera tool (Carvalho, et al, 2020). Inspect all energy sources in a stopped condition (International Standardization Organization, 2000). The use of information marks in the form of Lock Out/Tag Out (LOTO) (Gunara, 2017). In carrying out maintenance, the condition of the engine must be off and cut off the current in the engine (Ministerial Regulation, 2016).
6. Operational failures in looper machines can use inverse linear quadratic or predictive control systems (Choi, et al, 2007). The use of distance guards will limit and reduce potential danger zones from working employee access (International Standardization Organization, 2015). Checking the hydraulic system about once a week to avoid failure in the machine (Mustaqim, et al, 2020)
7. Failure to manually bind HRC products using distance guards will limit and reduce potential danger zones from working employee access (International Standardization Organization, 2015). Use of Personal Protective Equipment such as helmets, goggles, leather gloves, safety shoes, aprons, ear plugs, and masks (Ministerial Regulation, 2020).

Conclusion

In HRC production, there are five production units, namely reheating furnace, sizing press, roughing mill, finishing mill, and down coiler. Each of these units has different sources of potential failure such as engine damage, too fast engine rotation, cracks in the tool, engine leakage, failure to tie HRC products and slab pieces. The potential hazards resulting from failure are fire, explosion, exposure to high temperatures, entangled in the engine, and burns. In the results of the risk priority number in each HRC production unit, the focus of research is only taken from the assessment results with medium and high categories. In the results of the study there were seven equipment with medium category. In leakage and operational failure of the burner tool, an RPN value of 420 was obtained, refractory brick furnace cracks were 324, scale pieces bounced from the reservoir were 294, oil leaks in flat pass, work roll, and backup roll engines were 252, damage to roller table machines was 240, operational failures in machines looper of 240 , and manual binding failure of HRC product of 240. There are several control recommendations for seven HRC production equipment, namely the use of flame rod and ultraviolet sensor indicators, the use of ultrasonic test tools, the use of thermal camera tools, the use of thermal infrared cameras, the use of LOTO, the use

of distance guards, installation of spools, equipment maintenance, equipment inspection, and PPE use.

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