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Forming machine maintenance planning using the reliability centered maintenance (RCM) method at PT. KHI pipe industries

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ABSTRACT

PT KHI Pipe Industries is a member of the Krakatau Steel Group which operates in the manufacturing industry. The company's main activity is the production of high quality steel pipes for oil and gas. The problems that occurred were breakdowns 19 times in one year and damage to one of the components on the forming machine. Currently the company is still implementing a Corrective Maintenance system. Based on the problem, maintenance proposals need to be made using the Reliability Centered Maintenance (RCM) method to determine critical components, find out the correct Task Selection (Action Selection), and provide improvement proposals. Based on the results of RCM research, the critical component in the forming machine is the Squeeze Top Roll component which consists of Bearing, Shaft, Sleeve, Cover Sleeve, and Roll Top. Obtained a broken bearing with an RPN value of 378, LTA category B, and Time Directed action selection; broken cover bolt with RPN value of 324, LTA category B, and Condition Directed action selection; rocking roll with an RPN value of 180, LTA category D, and selection of the Finding Failure action; worn shafting with an RPN value of 144, LTA category D, and selection of the Finding Failure action. Proposed improvements for components include making a maintenance schedule according to the component's service life, selecting the NUTR65150H bearing type, modifying the greasing line, carrying out routine checks once a week, and improving the design of the shafting, roll, bearing and top squeeze.

ABSTRAK

PT KHI Pipe Industries merupakan anggota dari Krakatau Steel Group yang bergerak dibidang industri manufaktur. Kegiatan utama perusahaan adalah untuk produksi pipa baja berkualitas tinggi untuk minyak dan gas. Permasalahan yang terjadi yaitu *breakdown* sebanyak 19 kali dalam satu tahun dan rusaknya salah satu komponen pada mesin *forming*. Saat ini perusahaan masih menerapkan sistem *Corrective Maintenance*. Berdasarkan permasalahan, perlu dilakukan usulan perawatan dengan menggunakan metode *Reliability Centered Maintenance* (RCM) untuk menentukan komponen kritis, mengetahui *Task Selection* (Pemilihan Tindakan) yang tepat, dan memberikan usulan perbaikan. Berdasarkan hasil penelitian RCM komponen yang kritis pada mesin *forming* adalah komponen *Squeeze Top Roll* yang terdiri dari *Bearing*, *Shaft*, *Sleeve*, *Cover Sleeve*, dan *Roll Top*. Didapat *bearing* pecah dengan nilai RPN sebesar 378, LTA kategori B, dan pemilihan tindakan *Time Directed*; baut *cover* patah dengan nilai RPN sebesar 324, LTA kategori B, dan pemilihan tindakan *Condition Directed*; *roll* goyang dengan nilai RPN sebesar 180, LTA kategori D, dan pemilihan tindakan *Finding Failure*; *shafting* aus dengan nilai RPN sebesar 144, LTA kategori D, dan pemilihan tindakan *Finding Failure*. Usulan perbaikan untuk komponen diantaranya membuat jadwal *maintenance* sesuai dengan masa pakai komponen, pemilihan tipe *bearing* NUTR65150H, modifikasi jalur *greasing*, melakukan pengecekan rutin seminggu sekali, dan *improve* desain dari *shafting*, *roll*, *bearing*, dan *top squeeze.*

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1. Introduction

PT KHI Pipe Industries is a member of the Krakatau Steel Group which operates in the manufacturing industry. The company's main activity is the production of high quality steel pipes for oil and gas. Currently PT KHI Pipe Industries is trying to continuously strengthen its position as a manufacturing company to help meet pipe needs both nationally and internationally. Plant ERW 2 PT KHI Pipe Industries has four machines which are divided into production machines and process machines. After conducting observations and interviews with operators or production supervisors, it was discovered that the problems that occurred were breakdowns 19 times in one year, and damage to one component of the production machine, namely the forming machine part. In dealing with this problem, the company still implements a Corrective Maintenance system. The implementation of this system has not been effective, because component replacement is carried out when the component is damaged. The production process on a forming machine is the most important stage of pipe making, because in this machine the pipe material will undergo several stages of forming until the material is round and then the welding stage will be carried out. If damage occurs to the machine it will hamper the production process because the machine cannot function. Normally. The Forming Machine consists of 6 machines, namely, Breakdown machine, Cage Forming, Fin Pass, Sin Gate, HF Welder, and Squeeze Roll. One of the Forming machines that often hampers the production process is the Squeeze Roll machine with downtime of 10,196 minutes in April 2017 – March 2018. To carry out maintenance repairs, there are several maintenance methods that can be carried out, one of which is the Reliability Centered Maintenance (RCM) Method [1]. RCM is a process used to determine what must be done to ensure that all physical assets continue to do what users want them to do under current operating conditions [2]. RCM is based on the understanding that each asset is used to fulfill a specific function or function and that maintenance means doing whatever is necessary to ensure that the asset continues to fulfill its function to user satisfaction [3].

2. Research Methodology

2.1. System Selection and Information Collection

System selection can be based on several aspects of criteria, namely:

a. Systems that receive high attention because they relate to safety and environmental issues.
b. Systems that have preventive maintenance and/or high preventive maintenance costs.
c. Systems that have corrective maintenance actions and/or large corrective maintenance costs.
d. Systems that have a large contribution to the occurrence of shutdowns.

Information gathering serves to get a deeper picture and understanding of the system and how the system works. Defining system boundaries is used to define the boundaries of a system that will be analyzed with RCM, containing what should be included and what should not be included in the system, in the form of input and output. A system description is needed to understand the components contained in the system and how these components operate. Meanwhile, the functional block diagram identifies the system in detail and is a flow diagram of the functional flow of a system. System function is the performance expected by the system to operate. Functional failure is defined as the inability of a component or system to meet expected standards of performance.

2.2. Failure Mode Effect Analysis (FMEA)

Failure Mode Effect Analysis (FMEA) is a methodology used to evaluate failures that occur in a system, design, process or service. Potential failure identification is carried out by assigning a value or score to each failure mode based on the occurrence level, severity level and detection level [4]. Logic Tree Analysis (LTA) is a qualitative process used to determine the consequences caused by each failure mode. The aim of LTA is to classify failure modes into several categories so that later a priority level can be determined in handling each failure mode based on its category [5]. In the action selection stage, the appropriate action for a particular damage mode will be determined. If a preventive task is technically unprofitable to perform, the standard action to be taken depends on the consequences of the failure occurring. Some categories of preventive measures include [6]:

a. Condition Directed (CD) is an action that aims to detect. If symptoms of damage are detected, then repair or replacement of components will be carried out.
b. Time Directed (TD) is an action that focuses more on periodic cleaning activities.
c. Finding Failure (FF) is an action with the aim of finding hidden equipment damage through regular inspections.

3. Results and Discussions

3.1. System Selection and Information Collection

Table 1. Main Components of Forming Machines [7].

No	Komponen-komponen Utama Pada Mesin *Forming*	Kelas
1	Adjustment Motor	2
2	Squeeze Top Roll	1
3	Side Roll	1
4	Bottom Roll	1
5	Seam Guiding Unit	1
6	Scrafer	2
7	Scrap Winder	3

The material for implementing Reliability Centered Maintenance (RCM) is concentrated on the Squeeze Top Roll component which functions to form pipes before welding and during welding [8]. The following is a table of information regarding the systems in the Squeeze Top Roll component along with the function of each system:

Table 2. Squeeze Top Roll Component System Information [9].

No	Component Name	Component Functions
1	Bearing	As a driving axle
2	Shaft	As a bearing holder
3	Sleeve	To protect bearings and shafts To move the rotation
4	Cover Sleeve	Untuk menutup sleeve
5	Roll Top	Untuk memberi tekanan saat pembentukan pipa

3.2. System Description and Functional Block Diagram

The system boundaries on the Squeeze Roll machine are input, process and output. The input of this system is HRC (Hot Rolling Coil) which has gone through a forming process on a Sin Gate machine, then enters the welding process by melting the left and right sides of the HRC, and the output is a pipe. Creating a functional hierarchy of equipment systems by determining the functional hierarchy on forming machines is done by grouping each subsystem function that makes up the system. The hierarchy of functions of the Squeeze Top Roll component system can be seen in Figure 1 below:

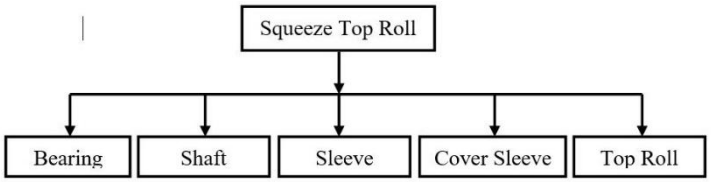

Figure 1. Functional Block Diagram for Squeeze Top Roll [10].

Table 3. System Functional Hierarchy [11][12].

Sistem	Subsistem	Komponen
Squeeze Top Roll	Bearing	-
	Shaft	Lock Nut KM19
	Sleeve	-
	Cover Sleeve	-
	Top Roll	-

3.3. Determination of System Function and Functional Failure

Functional failure analysis is an activity to describe each system, subsystem, and component or equipment and identify all functions with other systems or subsystems and identify all functional failures. Function failure analysis as follows [13][14]:

a. Bearing
   Bearings function as the drive shaft in the machine. In the functional diagram of the squeeze top roll section, it can be seen that the bearing does not have any other components.
b. Shaft
   The shaft functions as a bearing holder. In the functional diagram of the squeeze top roll section it can be seen that to carry out the function the Shaft has a KM19 Lock Nut component. The function of the KM19 Lock Nut is to lock the bearing and shaft.
c. Sleeve
   The sleeve functions as a protector for the bearing and shaft. The sleeve also functions to move the rotation. In the functional diagram of the squeeze top roll section, it can be seen that the sleeve does not have any other components.
d. Cover Sleeve
   Cover Sleeve functions as a sleeve cover. In the functional diagram of the squeeze top roll section, it can be seen that the sleeve cover does not have any other components.
e. Top Roll
   Top Roll functions to apply pressure when forming the pipe so that it becomes round. In the functional diagram of the top roll squeeze section, it can be seen that the top roll does not have any other components.

3.4. Determination of Failure Mode and Effect Analysis (FMEA)

Determining failure modes and effects (FMEA) is an analysis of failure modes and impacts by analyzing failures which places more emphasis on quantitative analysis and identifying the impact of the failure mode of a component on the system, sub-system, or on the component itself, including how to detect the failure mode [15]. Determination of S, O, and D ratings is determined by conducting direct interviews with workers.

Table 4. Failure Mode and Effect Analysis on Squeeze Top Roll [16][17].

Squeeze Failure	Effects of Potential Failure	S	Potential Causes	O	Control	D	RPN
The squeeze roll will not turn	Bearing broken	9	Overheating occurs	6	Use NUTR65150H bearings	7	378
	Shafting worn	6	Lack of lubricant	4	Provided with grease (lubricant)	6	144
	The cover bolt is broken	9	The bearing position is not in place	6	The bolts are tightened using loctite (hardener)	6	324
	Rocking roll	6	Shaft mount loose	5	Tighten the shafting cover bolts	6	180

From the results of the Risk Priority Number (RPN) calculation, it can be concluded that bearing rupture has the highest value. The highest RPN value indicates that there is a failure mode that must be repaired, which can be seen in the Task Selection table based on the RPN level as follows:

Table 5. Task Selection Based on RPN Level [18].

Rating	Clasification	Risk Priority Number
<100	N	No Maintenance (RTF)
100-200	L	Low Maintenance (or RTF)
200-400	M	Adequate Maintenance
400-600	MH	Aggressive Maintenance
600-800	H	Aggressive Maintenance (+maybe redesign)
800-1000	E	Aggressive Maintenance + redesign

Based on the Task Selection value at the RPN level, this high value is included in the Adequate Maintenance level (adequate action). Repairs will be carried out based on the causes of failure which have been analyzed using Failure Mode and Effect Analysis, so that we can find out the problems that occur so that repairs can be carried out.

3.5. Logic Tree Analysis

Logic Tree Analysis (LTA) is a qualitative measurement tool that aims to emphasize priorities and resources that must be allocated to each failure mode to classify failure modes, because failure modes are not the same.

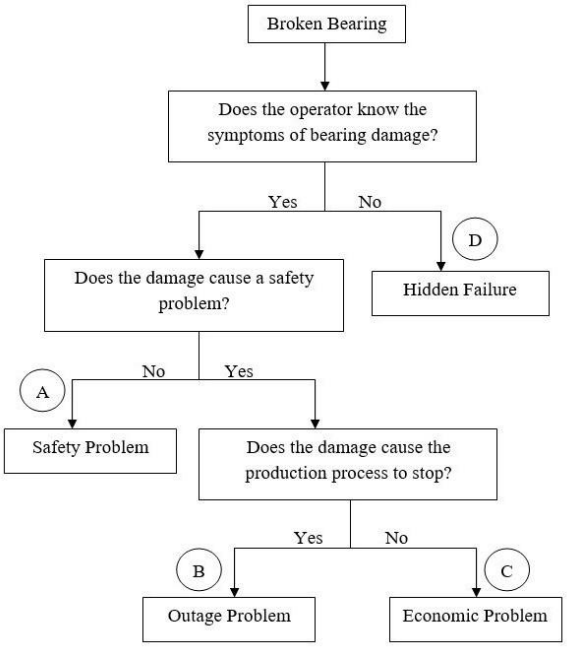

Figure 2. Logic Tree Analysis of Broken Bearing

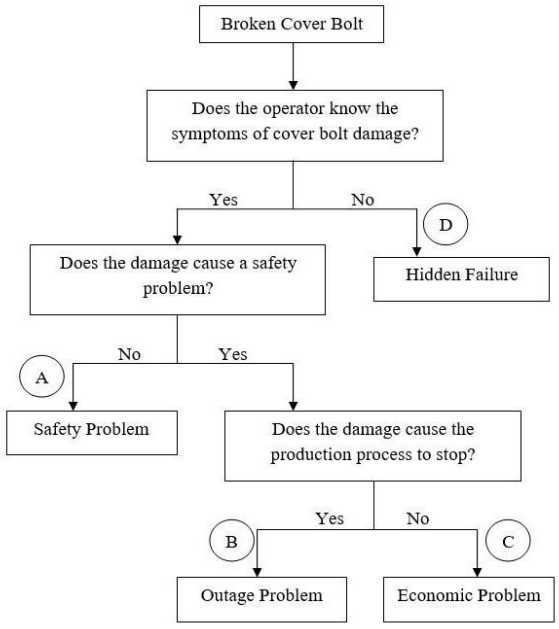

Figure 3. Logic Tree Analysis of Broken Cover Bolt

The Logic Tree Analysis table is as follows:

Table 6. Logic Tree Analysis

Squeeze Top Roll Failure	The effects of potential failure	Potential causes	Critically Analysis			
			E	S	O	Category
The squeeze roll will not turn	Bearing broken	Overheating occurs	Yes	No	Yes	B
	Shafting worn	Lack of lubricant	Yes	No	Yes	D
	The cover bolt is broken	The bearing position is not in place	Yes	No	Yes	B
	Rocking roll	Shaft mount loose	Yes	No	Yes	D

3.6. Task Selection

In the action selection stage, the appropriate action for a particular damage mode will be determined. If a preventive task is technically unprofitable to perform, the standard action to be taken depends on the consequences of the failure occurring. The following is a recapitulation of the selection of actions taken from Failure Mode and Effect Analysis and Logic Tree Analysis:

Table 7. Recapitulation of RCM Action Selection

No	Component	Failure Mode	RPN	LTA	Action Plan
1	Bearing	Bearing broken	378	B	Time Directed
2	Shafting	Shafting worn	144	D	Finding Failure
3	Cover Bolt	The cover bolt is broken	324	B	Condition Directed
4	Roll	Rocking roll	180	D	Finding Failure

From the data processing explanation above, there are many factors that cause failure in forming machines, especially in the Squeeze Top Roll machine. This failure factor will be resolved using the Fishbone Diagram. The proposed improvements are as follows:

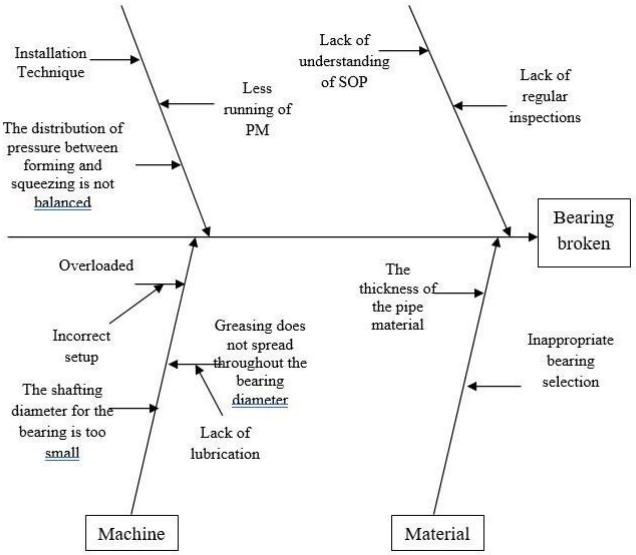

Figure 4. Fishbone diagram of bearing components

Based on the fishbone diagram, four causal factors were found, including humans, methods, materials and machines. It can be seen in the table as follows:

Table 8. Results of Analysis of Causes and Actions on Bearing Components

Factors causing disability		Reason	Action
Man	a. Lack of understanding of SOP b. Lack of regular inspections	a. Lack of training for workers b. Worker negligence	a. Provided regular training to workers b. The control schedule must be monitored and discipline and responsibility applied to workers
Method	a. Inappropriate installation technique. b. Less running of PM.	a. Bearing installation that is too loose. b. Maintenance does not match the service life of components.	a. Install bearings according to standards. b. Create a maintenance schedule according to the service life of the components.
Material	a. The thickness of the pipe material varies. b. Inappropriate bearing selection.	a. The thickness of the material causes the compressive force on the component to increase.	a. Check and continue to monitor the durability of components. b. Selection of bearing type NUTR65150H.
Machine	a. Greasing does not spread throughout the bearing diameter. b. Overloaded. c. The shafting diameter for the bearing is too small.	a. Lack of lubrication. b. Incorrect setup. c. Selection of shafting type not in accordance withthe bearing diameter size.	a. Greasing line modification. b. Carry out routine checks on the machine. c. Improve the design of shafting, roll, bearing, and top squeeze.

4. Conclusions

The conclusion of this article is:

1. The critical component in the Forming machine is the Squeeze Top Roll component which consists of Bearing, Shaft, Sleeve, Cover Sleeve, and Top Roll.
2. A broken bearing was found with an RPN value of 378, LTA category B, and Time Directed action was selected; broken cover bolt with RPN value of 324, LTA category B, and Condition Directed action selection; rocking roll with an RPN value of 180, LTA category D, and selection of the Finding Failure action; worn shafting with an RPN value of 144, LTA category D, and selection of the Finding Failure action.
3. Proposed improvements for components include making a maintenance schedule according to the component's service life, selecting the NUTR65150H bearing type, modifying the greasing lines, carrying out routine checks once a week, and improving the design of the shafting, roll, bearing and top squeeze.

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