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Analysis of Maintenance Activities on Drag Chain Machines To Optimize Failure Time Intervals Using Reliability Centered Maintenance (RCM) Approach

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ABSTRACT

Drag Chain is a material moving machine whose working method is to deliver material using a continuous dragging method. Drag chain is the optimal choice for cement production, because the chain with conveyor leaves on the right and left side drags along the bottom of the trough to transport the material in a closed state. Under these circumstances the drag chain components will tend to wear out, as the material interacts directly with the chain and can cause problems. This research will explain the maintenance process using the Reliability Centered Maintenance (RCM) approach is a maintenance system which is associated with statistics to find the value of the reliability of a component so that we can prevent failure by a combination of various actions.

Keyword: Chain conveyor, Drag chain, Maintenance, Reliability Centered Mintenance (RCM).

ABSTRAK

Drag Chain merupakan mesin pemindah material yang cara kerjanya adalah mengantarkan material dengan metode drag yang kontinyu. Drag chain merupakan pilihan optimal untuk produksi semen, karena rantai dengan daun konveyor di sisi kanan dan kiri menyeret sepanjang dasar bak untuk mengangkut material dalam keadaan tertutup. Dalam keadaan seperti ini komponen drag chain akan cenderung aus karena material berinteraksi langsung dengan rantai dan dapat menimbulkan masalah. Penelitian ini akan menjelaskan proses pemeliharaan dengan pendekatan Reliability Centered Maintenance (RCM) merupakan suatu sistem pemeliharaan yang dikaitkan dengan statistik untuk mencari nilai keandalan suatu komponen sehingga kita dapat mencegah kegagalan dengan kombinasi berbagai tindakan.

Keyword: Chain conveyor, Drag chain, Perawatan, Reliability Centered Maintenance (RCM).

1. Introduction

Drag Chain is a material transfer machine that works by delivering material with a continuous dragging method. In terminology, drag chain is a type of chain conveyor, which is defined as a walking chain system, because it consists of a series of chains designed to move in a circular, up and down or sideways right and left manner. The conveyor chain consists of supporting bearing blocks that maintain the unity of the chain links as it rotates. These chains can move large amounts of material quickly from one location to another.

The difference between drag chain and chain conveyor is that drag chain is a material transfer tool using the drag chain method, while chain conveyor is a material transfer system that uses a chain that keeps running. Drag chains are the optimal choice for cement production, as chains with conveyor leaves on their right and left sides drag along the bottom of the bin to transport material in a closed state. Under these circumstances drag chain components will tend to wear out, as the material interacts directly with the chain and can cause problems. For example, worn base plates and return rails will cause the chain to tilt and the material transfer process will become ineffective and can even cause the conveyor leaf to bend and cause more serious problems.

The maintenance process using the Reliability Centered Maintenance (RCM) approach is a maintenance system associated with statistical science to find the reliability value of a component so that we can prevent failure with a combination of various actions. Thus this paper will discuss the Reliability Centered maintenance method that will be applied to the drag chain engine so that the engine performance remains in an optimal state.

2. Method

This research will be conducted at PT Solusi Bangun Andalas Packing Plant Belawan located at Jl. Ujung Baru Port, Medan Belawan District, Belawan 1 Village, Medan City, North Sumatra, ID. This company is located on the edge of the high seas, because the raw materials produced from Aceh are sent by sea using cement transport ships and then will be managed into quality products that will be marketed to the Sumatra region using land transportation.

2.1. Object of Research

The object under study is a production machine component that has an important role in the smooth production process at PT Solusi Bangun Andalas located in Medan Belawan District. In this case the object of research is the Drag Chain machine.

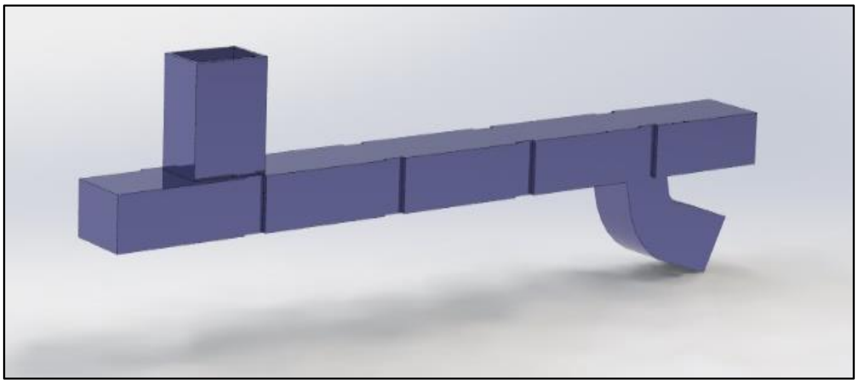


Figure 1 Object of Research

The reason the author chose drag chain as the object of research is because this component has a role as transportation of cement raw materials to continue to the next process. If the drag chain is damaged, production activities will automatically stop as a whole and will cause large losses.

The Drag Chain itself has very important main components, such as electric motors, gearboxes, bearings, sprockets, chains, chain plates, scrapper, pins, return rails, base plates, and covers. The production capacity at PT. Solusi Bangun Andalas is 250 tons / hour so that all these components must be taken into account so that they are able to work according to production capacity.

2.2. Data Processing Method

The data required in this research is done in the following ways:

1. Making direct observations of the object of research, namely the Drag Chain machine at PT. Solusi Bangun Andalas.
2. Reading the records owned by the company related to the required data.
3. Conduct interviews with supervisors and production employees who can provide information to solve problems.
4. Reading books and research journals related to the application of reliability and Drag Chain.

After obtaining the necessary data, the data is processed based on the concept of data processing can be seen in the following figure.

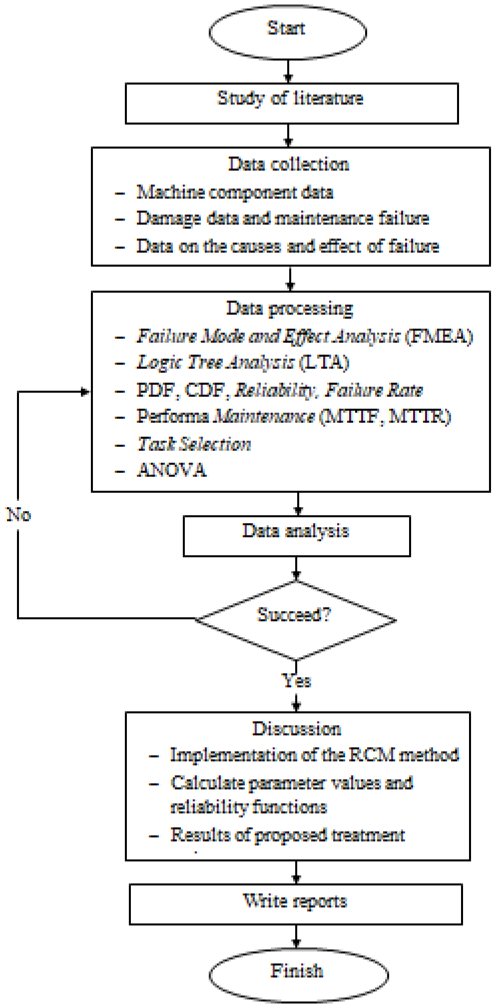


Figure 2. Flow Chart

3. Result and Discussion

3.1. Data on The Occurrence Time of Drag Chain Machine Failure

The data obtained is the result of records from PT. Solusi Bangun Andalas in the workshop or workshop section and the data taken in the span of the last 1 year starting from January 2022 to December 2022.

Table 1 Drag chain machine component failure list

Name of Component	Date of Breakdown	Failure Description	*Break down Time*	*Down Time*	*Set Up Time*
Return Rail	January 09th 2022	Scanning drag chain line A, found a skewed return rail.	223.2	150	120
Return Rail	February 13th 2022	Scanning drag chain line B, found a skewed return rail.	223.2	150	120
Cover	February 25th 2022	The drag chain body is low, making it prone to being exposed to the tide.	216	60	120
Roller	March 01st 2022	Drag chain roller detached and fell off the bearing	147	100	60
Bearing	March 24th 2022	Already entered the replacement schedule on the bearing (life time bearing)	136.2	100	90
Link wheel	April 07th 2022	Shrinking of the link wheel	120	80	100
Chain Leaves	July 03rd 2022	Bent chain leaf	260	242	120

Name of Component	Date of Breakdown	Failure Description	*Break down Time*	*Down Time*	*Set Up Time*
Chain Leaves	September 29th 2022	Twisted chain leaf	147	100	60
Bearing	November 10th 2022	Bearing wear so that it breaks	147	160	60
TOTAL (MINUTES)			1619.6	1142	850

3.2. Failure Mode and Effect Analysis (FMEA)

The determination of critical components in this study uses a direct approach method and uses the Failure Mode and Effect Analysis (FMEA) table tools to determine the RPN value of the drag chain machine which shows the level of importance of components that are considered to have a high risk, therefore requiring special treatment by carrying out maintenance repairs which can be seen in the FMEA table as follows:

Table 2. Failure Mode and Effect Analysis (FMEA)

No	Name Of Component	Functional Failure	Failure Mode	Effect of Failure	S	O	D	RPN
1	Return rail	There is a return rail that has tilted and the return rail tread bolt is bent	There is cement material that rubs continuously.	When working a lot of cement is not carried to the elevator bucket	7	3	4	**84**
2	Cover	Low ground clearance with drag chain body	Very easy to be submerged in tides / floods that have the potential for water to enter the body	Cement material should not be mixed with water, which has the effect of cement clumping until it hardens.	6	1	2	**12**
3	Roller	The drag chain roller is detached and falls off the bearing	The drag chain body expands slightly making the shaft roller far from the bearing	When working a lot of cement is not carried to the elevator bucket	6	2	4	**48**
4	Bearing	It has entered the bearing replacement schedule (Life time bearing) and the bearing is worn so that it breaks	The shaft rotation becomes heavy and unbalance	If the bearing breaks the shaft cannot rotate stably and can damage other components.	6	3	3	**54**
5	Link wheel	There is friction noise when the drag chain is running.	Shrinking the link wheel and thinning the return rail plate	Friction that is too over will cause the chain and return rail to wear out	5	4	3	**60**
6	Chain Leaves	There is friction sound	Skewed chain position	The material brought to the elevator bucket is not optimal and the base plate will be thinner and thinner.	7	4	4	**112**

3.3. Determining The Reliability Concept

The concept of reliability aims to determine the value of the component damage rate function so that it can be used to determine the failure time interval which aims to determine what action will be taken next, be it maintenance or replacing parts before failure occurs.

1. Chain Leaves

   The Weibull distribution parameter values obtained are.

   β = 1,5576 α = 81,5797 c = -6,4572

   The reliability function of a Leaf Chain component that follows the Weibull distribution is

   $$R(t) = exp\left(-\frac{t}{\alpha}\right)^{\beta}$$

   $$R(t) = exp\left(-\frac{213}{81{,}5797}\right)^{1{,}5576}$$

   $$R(t) = 0{,}8800$$

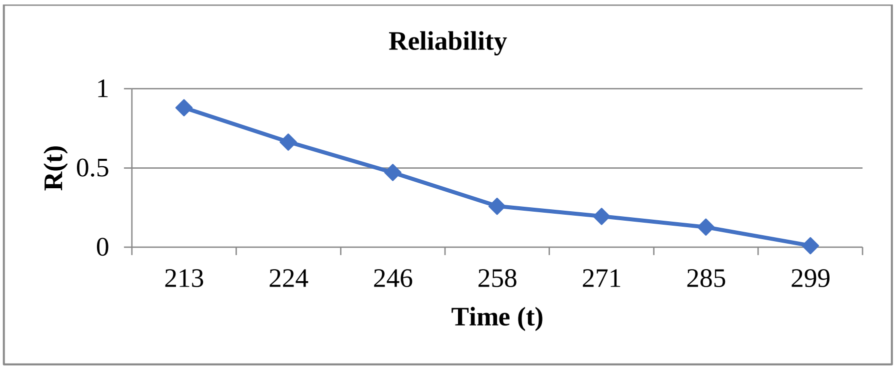
   The failure rate function of the Leaf Chain component that follows the Weibull distribution is

   $$H(t) = \frac{f(t)}{R(t)} = \frac{\beta}{\alpha}\left(\frac{t}{\alpha}\right)^{\beta-1}$$

   $$H(t) = \frac{1{,}5576}{81{,}5797}\left(\frac{213}{81{,}5797}\right)^{1{,}5576-1}$$

   $$H(t) = 0{,}0111$$

   Based on the data processing value of the reliability concept against time, the Weibull distribution graph for the reliability function and the failure rate function on the leaf chain component can be seen in the following figure.



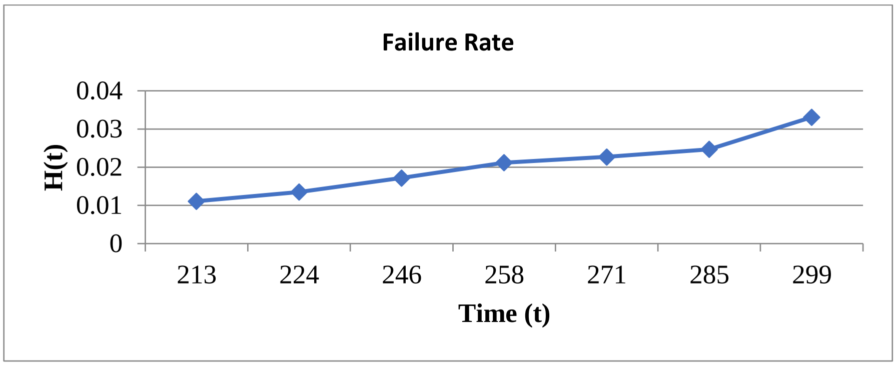


Figure 3. Reliability and Failure Rate Graphics Chain Leaves

2. Return rail

   The Weibull distribution parameter values obtained are.

   β = 2.0956 α = 87.5729 c = 9.3674

   The reliability function of a return rail component that follows the Weibull distribution is

   $$R(t) = exp\left(-\frac{t}{\alpha}\right)^{\beta}$$

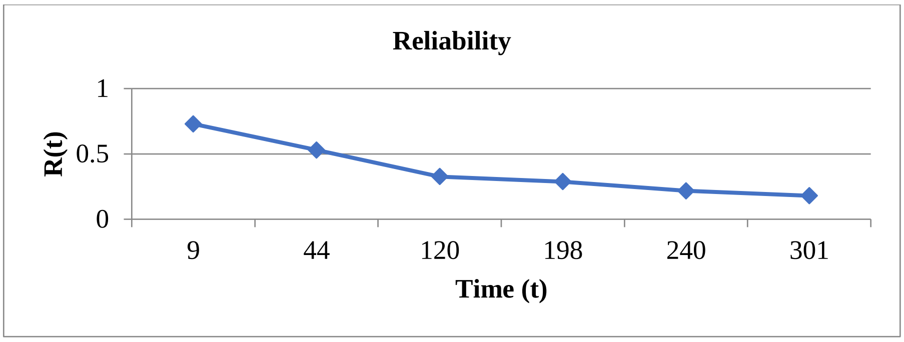
$R(t) = exp\left(-\frac{9}{87.5729}\right)^{2.0956}$
$R(t) = 0.7294$

The failure rate function of the return rail component that follows the Weibull distribution is

$$H(t) = \frac{f(t)}{R(t)} = \frac{\beta}{\alpha}\left(\frac{t}{\alpha}\right)^{\beta-1}$$

$$H(t) = \frac{2.0956}{87.5729}\left(\frac{9}{87.5729}\right)^{2.0956\text{-}1}$$
$H(t) = 0.0063$

Based on the data processing value of the reliability concept against time, the Weibull distribution graph for the reliability function and the failure rate function on the return rail component can be seen in the following figure.



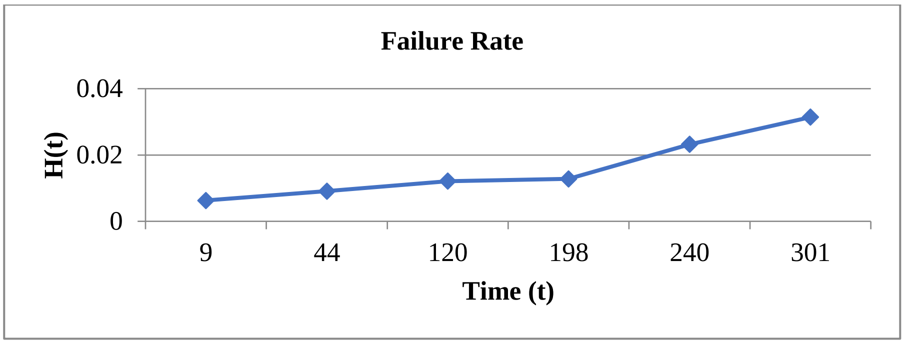


Figure 4. Reliability and Failure rate graphics return rail

3. Link wheel
   The Weibull distribution parameter values obtained are.

β = 1,5576 α = 81,5797 c = -6,4572

The reliability function of a Link wheel component that follows the Weibull distribution is

$R(t) = exp\left(-\frac{t}{\alpha}\right)^{\beta}$
$R(t) = exp\left(-\frac{127}{94{,}0098}\right)^{2{,}6546}$
$R(t) = 0{,}8023$

The failure rate function of the Link wheel component that follows the Weibull distribution is

$H(t) = \frac{f(t)}{R(t)} = \frac{\beta}{\alpha}\left(\frac{t}{\alpha}\right)^{\beta-1}$
$H(t) = \frac{2{,}6546}{94{,}0098}\left(\frac{127}{94{,}0098}\right)^{2{,}6546-1}$

$H(t)$ = 0,0034

Based on the data processing value of the reliability concept against time, the Weibull distribution graph for the reliability function and the failure rate function on the Link wheel component can be seen in the following figure.

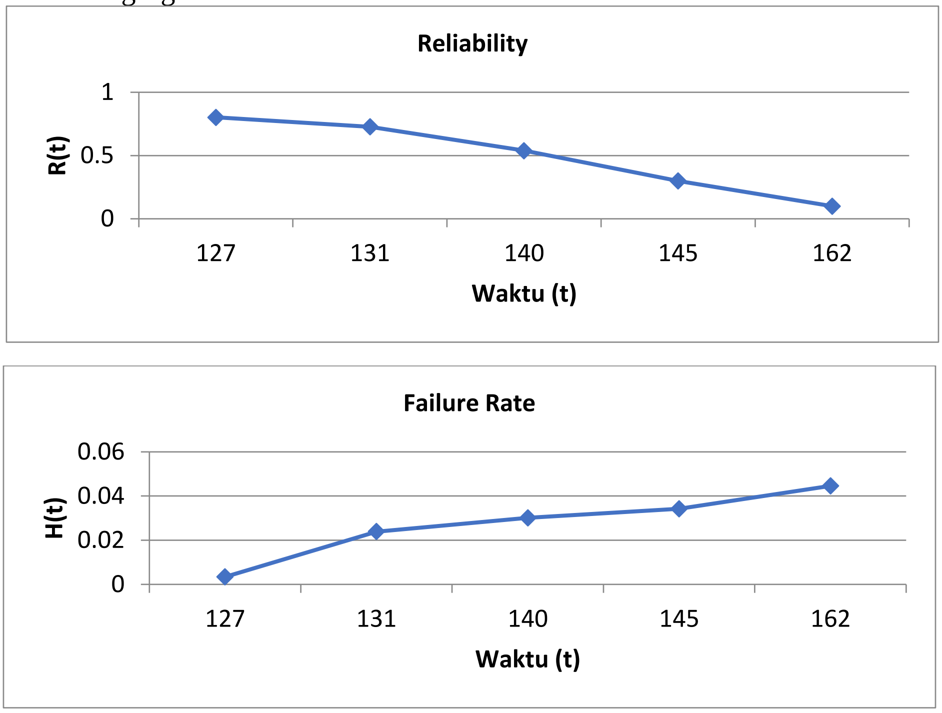


Figure 5. Reliability and Failure rate graphics Link wheel

3.4. *Mean Time To Failure* (MTTF) and *Mean Time To Repair* (MTTR)

After knowing the value of the shape parameter (β) and scale parameter (α) of the weibull distribution on the concept of critical component reliability, then the calculation of mean time to failure (MTTF) and mean time to repair (MTTR) on the components of the leaf chain, return rail, and wheel link in accordance with the distribution used to determine the maintenance indicators that play an important role for companies that can later consider increasing uptime (production time) while reducing downtime.

1. Chain Leaves

$$\text{MTTF} = \frac{1}{\lambda} = \frac{1}{0{,}0111} = 90 \text{ days}$$

$$\text{MTTR} = \alpha\, r\left(1+\frac{1}{c}\right) = 81{,}5797\ .\ 1{,}842\left(1+\frac{1}{6{,}4572}\right) = 22{,}54 \text{ days}$$

$$\text{MTBF} = \frac{(Total\ Available\ Time - Time\ Lost)}{Number\ Of\ Shutdowns}$$

$$= \frac{(478.689{,}6\ menit - 1.244\ menit)}{2}$$

$$= 238.722{,}8 \text{ minutes/year} = 165{,}77 \text{ day/year}$$

From the results of the above calculations, the mean time to failure of the leaf chain component is 90 days, the mean time to repair is 22.54 days, and the mean time between failure is 165.77 days.

2. Return Rail

$$\text{MTTF} = \frac{1}{\lambda} = \frac{1}{0{,}0063} = 158{,}73 \text{ days}$$

$$\text{MTTR} = \alpha\, r\left(1+\frac{1}{c}\right) = 87{,}5729\ .\ 2{,}255\left(1+\frac{1}{9{,}3674}\right) = 21{,}1 \text{ days}$$

$$\text{MTBF} = \frac{(Total\ Available\ Time - Time\ Lost)}{Number\ Of\ Shutdowns}$$

$$= \frac{(478.689{,}6\ menit - 986{,}4\ menit)}{2}$$

$$= 238.851{,}6 \text{ day/year} = 165{,}86 \text{ day/year}$$

From the results of the above calculations, the mean time to failure of the return rail component is 158.73 days, the mean time to repair is 21.1 days, and the mean time between failure is 165.86 days.

3. Link Wheel

$$\text{MTTF} = \frac{1}{\lambda} = \frac{1}{0{,}0034} = 294{,}1 \text{ days}$$

$$\text{MTTR} = \alpha\, r \left(1 + \frac{1}{c}\right) = 94{,}0098 \,.\, 2{,}531 \left(1 + \frac{1}{12{,}0609}\right) = 19{,}72 \text{ days}$$

$$\text{MTBF} = \frac{(Total\ Available\ Time - Time\ Lost)}{Number\ Of\ Shutdowns}$$

$$= \frac{(478.689{,}6\ menit - 600\ menit)}{2}$$

= 239.044,5 minutes/year = 166 day/year

From the results of the above calculations, the mean time to failure of the wheel link component is 294.1 days, the mean time to repair is 19.72 days, and the mean time between failure is 166 days.

3.5. Task Selection

After analyzing the failures and also calculating the reliability of the components, the proposed maintenance planning strategy is obtained. Whether it is preventive maintenance (PM), predictive maintenance (PdM), or corrective maintenance (CM) can be seen as follows:

Table 3. Task Selection

No	Equiptment	Function	Function Failure	Failure Mode	Consequences Evaluation				Maintenance Category
					H	***S***	***E***	***O***	
1	Leaf chain	Carrying cement material	There is a friction sound, The chain leaf is bent	Skewed chain position	Y	N	Y	N	PdM/ CM
2	Return Rail	Chain path as well as to maintain the stability of the chain so as not to tilt	There is a return rail that has been tilted, The return rail tread bolt is bent	There is cement material that rubs continuously .	Y	N	Y	Y	*PM/ CM*
3	Wheel link	As a wheel that runs on the return rail plate to minimize friction	There is a friction sound when the drag chain is running.	Shrinking of the link wheel and thinning of the return rail plate	N	N	Y	N	PdM/ CM
4	Bearing	Shaft bearings to keep rotation stable without damaging the housing	It has entered the bearing replacement schedule (Life time bearing), Bearing wear so that it breaks	Shaft rotation becomes heavy and unbalance (loose)	Y	N	Y	Y	*PM/ PdM*
5	Roller	Sprocket holder	The drag chain roller is detached and falls off the bearing	The drag chain body expands slightly making the shaft roller	Y	N	Y	Y	*PM/ PdM*

No	Equiptment	Function	Function Failure	Failure Mode	Consequences Evaluation				Maintenance Category
					H	***S***	***E***	***O***	
				far from the bearing					
6	Body/Cover	Material protector	The low distance between the base of the ground surface and the drag chain body	Very easy to be submerged in tides / floods that have the potential for water to enter the body	Y	N	Y	Y	*PdM*

In the table above, we can see the consequences or impacts that arise due to failures in equiptment (Consequence Evaluation) which include Hidden Failure (H), Safety Problem (S), Economic Problem (E), Outage Problem (O).

1. Hidden Failure (H), is a failure mode that has a direct impact, but if no action is taken it can become a serious failure and even trigger other failures.
2. Safety Problem (S), is a failure mode that can endanger the safety and even death of a person.
3. Economic Problem (E), is a failure mode that affects the company's economy including repair costs.
4. Outage Problem (O), is a failure mode that can cause the component work system to stop completely or partially so that it can affect plant operations.

Before making improvements, it is necessary to analyze the factors that cause failures in the drag chain machine using a fishbone diagram. The fishbone diagram on the drag chain machine pays attention to four factors, namely material factors, environmental factors, machine factors, and human factors. Due to these factors that affect the decline in productivity and efficiency on the drag chain machine itself.

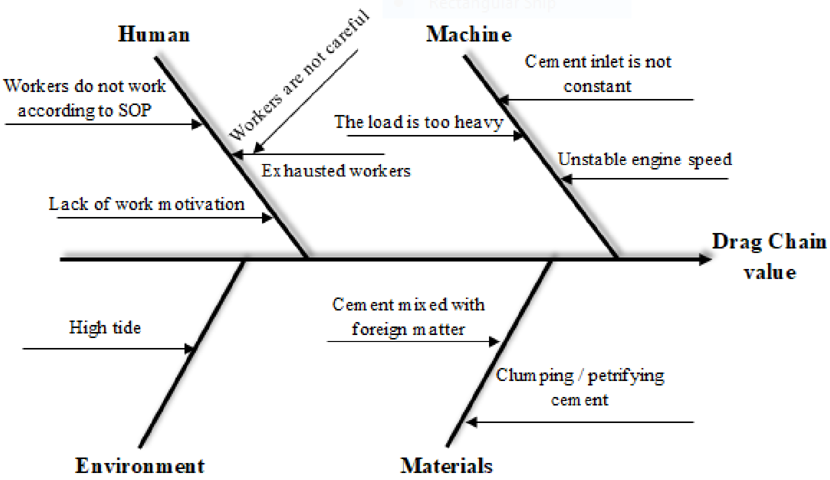


Figure 6. Fishbone Diagram drag chain performance

Apart from the proposed maintenance planning strategy, the maintenance process carried out by workshop mechanics at PT. Solusi Bangun Andalas to overcome the failure of the drag chain component can be seen in the following table:

Table 3.4 Maintenance overcoming drag chain component failure

No	Component	Mechanical Solution	Photos	
			Before	After
1	Leaf chain	Repairing the chain leaf by welding, which is then returned to its original shape.		
2	Return Rail	Repairing the return rail by welding, then returning it to its original shape.		
3	Wheel link	Replacing the old link wheel with a new link wheel by dismantling the pin on the chain.		
4	Bearing	Replace the new bearing with type F209.		
5	Roller	Repairing the roller and replacing the lock nut.		

No	Component	Mechanical Solution	Photos	
			Before	After
6	Body/Cover	Raising the tread from 17.5 cm to 62.5 cm.		

4. Conclusion

Based on the analysis and description of the research above, it was found that drag chain machine damage from January 2022 to December 2022 primarily affected the chain leaf, return rail, bearing, and roller components, with Risk Priority Numbers (RPN) of 112, 84, 60, 54, and 48 respectively, where higher RPN values indicate greater criticality or risk of failure. The top three components with the highest RPN values are the chain leaf, return rail, and link wheel, which, according to the Weibull distribution pattern, have reliability values of 88% with a Time to Failure (TTF) of 213 days and Mean Time to Failure (MTTF) of 90 days for the chain leaf, 73% with a TTF of 9 days and MTTF of 158 days for the return rail, and 80% with a TTF of 217 days and MTTF of 294 days for the link wheel. The analysis further reveals that the reliability values decrease over time, indicating that the machine is likely to experience failures in the future. Therefore, it is necessary to implement appropriate maintenance actions to optimize the failure time interval: predictive maintenance combined with corrective maintenance for the chain leaf and link wheel, preventive maintenance combined with corrective maintenance for the return rail, and preventive maintenance combined with predictive maintenance for the bearings and rollers.

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