Maintenance Analysis of Injection Machines Using the Reliability Centered Maintenance Method at PT Sinar Harapan Plastik

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Abstract. PT Sinar Harapan Plastik is a company that produces children's toys in the form of toy cars and toy bicycles from plastic material. After the identification, it concluded that the injection machine used for the production process experienced downtime. Thus, corrective action was needed to fix it. The downtime that occurred on the injection machine during the January-November 2019 period was 773.17 hours. This study aims to determine the critical components and recommend the selection of actions on the critical components. The method used to analyze machine failure is Reliability Centered Maintenance (RCM). Based on the FMEA analysis, the critical components were obtained, namely, the hydraulic motor pump coupling rubber, cross-head link, and magnetic contactor. Based on the LTA analysis, the failure of each component can be categorized, namely, the hydraulic motor pump coupling rubber including the hidden failure category (D), cross head link, and magnetic contactor including the outage problem category (B). The recommended actions for these components are time-directed (TD) on the hydraulic motor and magnetic contactor pump coupling rubber components and condition-directed (CD) on the crosshead link component.
Keywords: Downtime, FMEA, LTA, Injection Machine, RCM

1. Introduction

Inappropriate machine or equipment maintenance can cause damage to the machine or equipment such as loss of setup time, long adjustments when starting the production process, decreased machine production performance and produces many rejected products. If allowed to continue, it can cause substantial economic losses and can reduce the productivity and efficiency of machines or equipment[1]. Maintenance is a preventive measure aimed at minimizing or even avoiding damage to facilities, equipment or machines by ensuring the level of reliability and readiness and minimizing machine maintenance costs. In general, the purpose of maintenance is as follows[2]:

a. Ensure the safety of users who are operating the facility.
b. Guarantee the operational readiness of the machine or equipment needed in urgent conditions.
c. Extend the service life of facilities, equipment or machines.
d. Guarantee the availability and reliability of facilities, equipment or machines both in terms of maintenance and technical costs, so that they can be used as optimally as possible.

PT Sinar Harapan Plastik is one of the companies engaged in the manufacturing industry, especially in making children's toys in the form of toy cars and toy bicycles from plastic. To be able to produce products that comply with SNI and ISO standards, machines must be in optimal conditions. Thus, they must be balanced with good and scheduled maintenance so the machines are always in a state that is ready to operate. The problem that occurs is the machines used for the production process experience downtime. If this continues, it can cause a delay in the production process which this condition can lead to decreasing factory productivity due to failures that occur.
PT Sinar Harapan Plastik's production floor has 37 injection machines with different tonnage capacities. The company needs to know whether the machines are in a condition that is ready to operate. The downtime that occurred during the January-November 2019 period of 773.17 hours was caused by engine failure. Based on the high downtime, several machines contributed the highest downtime including injection machine No. 15 (Yan Hing) for 322.8 hours of downtime, injection No. 26 (Toshiba) for 38.5 hours of downtime, injection No. 27 (Toshiba) for 83 hours of downtime, injection No. 32 (Mitsubishi) for 23.5 hours of downtime and injection No. 34 (Yan Hing) for 192.5 hours of downtime. The huge amount of downtime that occurs can cause losses for the company, such as the rejected products hampering the production process, and the production's inability to meet the target. Based on this, to overcome problems that occur during machine downtime, preventive measures are needed.
This study aims to identify the cause of high downtime on the injection machine, determine critical components using Failure Mode and Effect Analysis (FMEA) and determine the correct machine maintenance action for each critical component that causes failure in the injection machine subsystem using Logic Tree Analysis (LTA).

2. Methods

The object of the research was components that were damaged in injection machines, totalling 37 units, in the production area at PT Sinar Harapan Plastik. The data collected are the production process, how the injection machine works, machine maintenance techniques, critical components of the injection machine, and corrective actions taken when there is damage to the machine, especially injection machines No. 15 (Yan Hing), Injection No. 26 (Toshiba), Injection No. 27 (Toshiba), Injection No. 32 (Mitsubishi) and Injection No. 34 (Yan Hing). In addition, data related to machine downtime and types of machine damage are also needed. Data processing is carried out by following the steps in implementing Reliability Centred Maintenance (RCM) as follows:

1. System Selection and Information Collection
   The first stage is the selection of machines and collecting information related to injection machines at PT Sinar Harapan Plastik. Several aspects need to be considered in system selection, which can be based on several aspects of the criteria, namely [3]:
   a. A system that pays more attention to the user and environmental safety.
   b. A system that has corrective actions and high repair costs on machines.
   c. A system that has a major influence on the occurrence of machine breakdown disrupts the production process.
2. Creation of Functional Flow Block Diagram (FFBD)
   At this stage, a system will be described based on the function or usability of the subsystem components within it by making the injection machine subsystem function flow using a Functional Flow Block Diagram (FFBD). System descriptions and function block diagrams are depictions of the main functions of the system by decomposing the system, function block diagrams, system input and output, equipment historical data, and the system work breakdown structure (SWBS) that must be developed [3].
3. Failure Mode and Effect Analysis (FMEA)
   FMEA aims to predict which components of a subsystem are at risk of failure. Failed components are analysed for each failure mode based on the functional failure, the impact of the failure, and the value of the Risk Priority Number (RPN) [4].
4. Calculating Risk Priority Number (RPN)

At this stage, the failed components are analysed and the Risk Priority Number (RPN) value is obtained. In FMEA analysis, an RPN value is needed which is associated with three variables, namely severity, occurrence, and detection. RPN can be written with the following equation [5].

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

5. Determining Logic Tree Analysis (LTA)
   At this stage, LTA is used to determine the consequences of each component failure. LTA is a qualitative process that is used to determine the impact of each failure mode. The information contained in the LTA includes an explanation of malfunctions in components of a sub-system, mode of failure to components of a sub-system, criticality analysis, and other required information. The criticality analysis can be adjusted based on four categories, namely: evident, safety, outage, and category.
6. Determining Action Plan
   At this stage, the appropriate action is selected for the failure mode based on the results of FMEA and LTA. Action selection aims to provide the appropriate action for a particular failure mode [3]

3. Result and Discussion

This research is limited to maintenance planning for critical components in the injection machine subsystem using the Reliability Centred Maintenance (RCM) approach to identify the causes of injection engine damage and determine the maintenance actions to take. The data used is machine downtime data for the period January - November 2019.

3.1. Component subsystems dan the frequency of failure

Component data and the frequency of failure on injection machines during the period January-November 2019 are depicted in table 1.

Table 1. Frequency of Failure January-November 2019

Sub Systems	Components	Frequency
Injection Unit	Screw Head	1
	Heater	7
	Hydraulic Motor	1
	Hydraulic Motor Hose	1
	Coupling Hydraulic Motor Rubber Pump	6
	Pipa Hydraulic	2
	Servo Pump	1
Clamping Unit	Fixed Platen	5
	Cross Head Link	6
	Cross Head	1
	Drat Mold	1
Tempering Unit	Magnetic Contactor	6
	Driver Fan	1
	MCCB	1
Control System	Monitor Panel Injection	6

3.2. System and Functional Flow Block Diagram

The function of the Injection Molding system is to mold a product made of plastic material with a certain shape and size. In the process, this machine gets a hot temperature and applies pressure by using a tool in the form of a mold (figure 1).

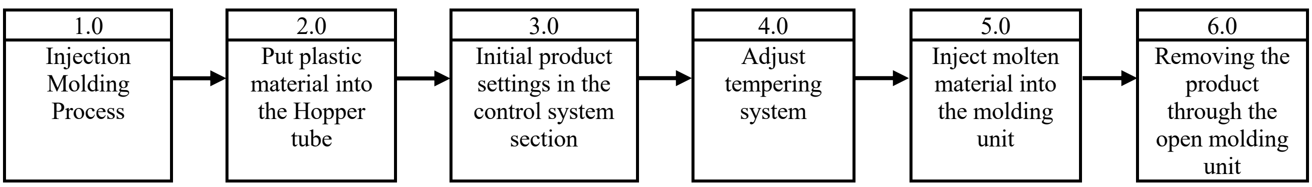

Figure 1. Functional Flow Block Diagram on Injection Machine

- System Work Breakdown Structure (SWBS)

  Based on the data, heaters, rubber couplings, hydraulic motor pumps, cross head links, fixed plates, magnetic contactors, and injection monitor panels are the components that experience the most failures with the frequency of damage being six times, two times, three times, two times. The SWBS can be seen in table 2.

Table 2 System Work Breakdown Structure (SWBS) Injection Machine

Machine	Code	Sub Systems	Code	Component
Injection	A	Injection Unit	A.1 A.2	Heater Hydraulic Motor Pump Coupling Rubber
	B	Clamping Unit	B.1 B.2	Cross Head Link Fixed Platen
	C	Tempering System	C.1	Magnetic contractor
	D	Control System	D.1	Injection Monitor Panel

- Describing Systems function and system failure.

  The description of the system function and failure of the injection machine can be seen in table 3.

Table 3. Component Functions and Failures

Function Number	No of Functional Failure	Functional Description	Functional Failure
A.1		Heating the material carried by the screw from the hopper	
	A.1.1		Abnormal temperature
A.2		Driving the hydraulic motor pump, Providing oil supply to the Hydraulic	
	A.2.2		The oil supply didn't work
B.1		Touching and controlling mold unit movement	
	B.1.1		The machine's open-close unit didn't work
B.2		Supporting the tie bar	
	B.2.2		Unprecition Mold installation
C.1		Connecting and disconnecting power	
	C.1.1		Abnormal temperature
D.1		Setting the working process of the machine, determining the machine parameters remain constant	
	D.1.1		Monitor Panel Injection is not working

3.3. Failure Mode and Effect Analysis (FMEA)

In the FMEA analysis, interviews were conducted with the Head of Maintenance and the Head of the Injection Team to determine the severity and detection values. In determining the value of occurrence, researchers use table 1 which shows the frequency of occurrence. In the FMEA analysis stage, RPN values are generated which are related to severity, occurrence, and detection. The FMEA table was discussed with the head of the maintenance division and the head of the injection team to determine severity and detection values. Based on the results of the FMEA analysis, three critical components were obtained, namely the hydraulic motor pump coupling rubber, cross head link, and magnetic contactor. The FMEA analysist can be seen in table 4 and the RPN value for each injection machine component obtained can be seen in table 5.

Table 4. *Failure Mode and Effect Analysis* (FMEA)

Major Sub system	Subsystem Function	Functional Failure	Component	Failure Mode	OCC	Failure Causes	DET	Failure Effect	Sev	RPN
Injection Unit	Heating the material carried by the screw from the hopper	Abnormal temperature	Heater	Heater failure	7	The service life has been exceeded, the cable is broken due to molten material	2	Uneven temperature	5	56
	Driving the hydraulic motor pump, Providing oil supply to the Hydraulic	The oil supply didn't work	Coupling Hydraulic Motor Rubber Pump	Coupling Hydraulic Motor Rubber Pump failure	6	Short service life, Coupling rubber becomes brittle	6	The machine can't work	6	216
Clamping Unit	Touching and controlling mould unit movement	The machine's open-close unit didn't work	Cross Head Link	Cross Head Link failure	6	Broke because of friction, Oil lubricant didn't work properly	4	The machine can't work	6	144
	Supporting the tie bar	Unprecicition Mould installation	Fixed Platen	Fixed Platen failure	5	Service life, friction open-close mould fraction	2	Unprecition	4	40
Tempering Unit	Connecting and disconnecting power	Abnormal temperature	Magnetic contractor	Magnetic Contactor failure	6	Short service life, worn coil	4	No power for the machine to operate	6	144
Control System	Setting the working process of the machine, determining the machine parameters remain constant	Monitor Panel Injection is not working	Monitor Panel Injection	Monitor Panel Injection failure	6	Short circuit, The electric current does not match the resistance value is very small	2	Machine can't work	6	72

Table 5. RPN Value of Injection Machine

No	Spare parts	RPN
1	Coupling Pump Hydraulic Motor Rubber	216
2	Cross Head Link	144
3	Magnetic contractor	144
4	Monitor Panel Injection	72
5	Heater	56
6	Fixed Platen	40

3.4. Logic Tree Analysis (LTA)

The process of making the LTA table was discussed with the Head of Maintenance and the Head of the Injection Team. The results can be seen in Table 6. Based on the results of the LTA analysis, it can be seen that the damage that occurs to the injection machine is an outage, which causes all or part of the machine to stop and hidden failure is difficult to detect by the operator so it can cause losses for the company.

Table 6. Logic Tree Analysis (LTA)

Major Subsystem	component	Failure Mode	Failure Causes	Criticality Analysis			
				Evident	Safety	Outage	Category

Injection Unit	Coupling Pump Hydraulic Motor Rubber	Coupling Pump Hydraulic Motor Rubber failure	Short service life, Coupling rubber becomes brittle	Y	N	Y	D
Clamping Unit	Cross Head Link	Cross Head Link broken	Broke because of friction, Oil lubricant didn't work properly	Y	N	Y	B
Tempering System	Magnetic contractor	Magnetic Contactor failure	Short service life, worn coil wear out	Y	N	Y	B

3.5. Recommendation of Treatment Action

Based on the results of the selection of actions on the critical components, several recommendations for the selection of actions were obtained. The results of action selection based on failure causes in FMEA and LTA can be seen in table 7.

Table 7. RCM Action Selection

Major Subsystem	Spare Part	RPN	LTA Category	Failure Causes	Action Plan
Injection Unit	Coupling Hydraulic Motor Rubber Pump	216	D	Short service life, Coupling rubber becomes brittle	TD
Clamping Unit	Cross Head Link	144	B	Broke because of friction, Oil lubricant didn't work properly	CD
Tempering System	Magnetic contractor	144	B	Short service life, worn coil wear out	TD

Based on table 7, we can classify the results to:

1. Condition Directed (CD) maintenance action
   The actions taken are aimed at detecting damage by visually checking, checking the tools, and observing several existing data. If during the detection process there are indications of damage, repairs will be carried out. The components that are planned in this maintenance action are cross-head links. The maintenance actions that can be taken can be seen in table 8.

Table 8. Condition Directed (CD) Maintenance Action Plan

No	Component	Condition Directed (CD) maintenance action
1	Cross Head Link	Visual checking on Cross Head Link.
		Checking the function of the Cross Head Link when the movement opens and closes the moulding. A movement must be smooth and not jammed
		lubricating the moving parts of the Cross Head Link before carrying out production.

2. Time Directed (TD) Maintenance Action
   The actions taken are aimed at avoiding component failures that focus on replacing machine components regularly based on historical failure data. The components that are planned in this maintenance action are the hydraulic motor pump coupling rubber and magnetic contactor. A comparison of previous treatment actions with recommended treatment actions can be seen in table 9.

Table 9. Comparison of Machine Maintenance

No	Components	Prior Care Measures	Treatment Action Recommendations	Function
1	Coupling Pump Hydraulic Motor Rubber	Corrective Maintenance (CM)/ Run to Failure (RTF)	TD	Avoiding potential component failures by focusing on machine component replacement activities carried out by Preventive Maintenance

2	Cross Head Link	Corrective Maintenance (CM)/ Run to Failure (RTF)	CD	Minimize potential damage by detecting. If during the detection process there are symptoms of equipment damage, repair or replacement of components will be carried out.
3	Magnetic Contractor	Corrective Maintenance (CM)/ Run to Failure (RTF)	TD	Avoiding potential component failures by focusing on machine component replacement activities carried out by Preventive Maintenance

3. Run to Failure (RTF) Maintenance Action
   RTF is the act of replacing components after a component is damaged. RTF action is an action used in the maintenance of injection machines at PT Sinar Harapan Plastik.

4. Conclusion

1. The high downtime rate of 773.17 hours during the January-November 2019 period in the production area at PT Sinar Harapan Plastik was caused by several factors including machine factors, human factors, and method factors.
2. Based on the results of the FMEA analysis, three critical components were found that caused the failure of the injection machine sub-system, namely the Hydraulic Motor Pump Coupling Rubber with an RPN value of 216, Cross Head Link with an RPN value of 144, and Magnetic Contactors with an RPN value of 144.
3. There are two components, namely Rubber Coupling Pumps Hydraulic Motors, and Magnetic Contactors which are planned with Time Directed (TD) maintenance actions, and one Cross Head Link component which is planned with Condition Directed (CD) maintenance actions.

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