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Analysis of Machine Maintenance Processes by using FMEA Method in the Sugar Industry

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Abstract. Sugar is the daily basic need of human life. It is made from cane trees and manufactured using a milling machine in the early stages. This machine is operated 24 hours per day; consequently, it should be in a good condition and the company must be able to ensure the machine can run well by scheduling regular maintenance. This study aimed to investigate the potential failure of manufacturing process to provide some recommendations for improvement. Failure Mode and Effect Analysis (FMEA) method was applied to analyze the situation, and Logic Tree Analysis (LTA) was implemented to classify the types of improvement. This study found 13 failure modes, including a loose hammer tip, a broken end of the cutter, a non-balanced hammer rotation, a broken hammer handlebar, a broken wheel bearing, a loose switch, a loose split pen, a loose fastener bolt, an overload, a destroyed rubber seal, a broken turbine coupling, a broken screw-bolt, and a hollow roller. Meanwhile, the classification of improvement consisted of 3 categories namely safety problem (A), outage problem (B), and economic problem (C). Subsequently, the A category recommended setting up the machine in accordance with SOP while the B category recommended inspecting the machine routinely and preparing parts. In addition, the C category recommended performing accurate installation, lubrication, and cleaning.

Keywords: Milling Machine, FMEA, LTA, Preventive Maintenance, Failure Mode

1. INTRODUCTION

One of the operation elements that affect the quality of production is the machines used because a continuous machine use can cause a lot of trouble and wear. To prevent trouble, maintenance should be done [1] including repair, arrangement, and replacement of parts in accordance with the schedule [2].

In the sugar industry, the milling machine is the main machine in the initial sugarcane processing operated for 24 hours per day. This process uses the flow shop system operating from the beginning to the end in sequence. If there is any trouble in the milling station, it cannot proceed to the next production stage. This condition should not take place; therefore, preventive maintenance should be regularly performed.

Failure Mode and Effect Analysis (FMEA) method is a systematic process for identifying potential failures of designs and processes with the purpose of minimizing or eliminating these failures [3]. In this study, FMEA method was utilized as a tool to identify potential machine failures by considering the Risk Priority Number (RPN).



This paper focused on proposed preventive maintenance for the milling station to prevent potential machine failures. This study also provided some recommendations for improvement which focused not only on failure modes with the highest rating based on the Risk Priority Number (RPN) but also on all failure modes considered as trouble. This is because, if a failure mode even with the smallest Risk Priority Number (RPN) is ignored, problems such as high repair costs or threat to the operator and work environment will occur.

To identify the cause of the failure and failure modes that are the most influential on the machine, the FMEA method (Failure Mode and Effect Analysis) was employed while LTA (Logic Tree Analysis) was used to find out the failure mode category for the following repair steps that should be done to prevent failure [4].

2. METHODS

2.1 Survey

A survey by interviewing the supervisor was done to identify the ongoing production process of the milling machine as well as to find out the detailed conditions of the machine.

Further survey was conducted by distributing questionnaires to 15 workers for assessing the level of severity, occurrence, and detection of machine failure. The workers were machinist assistants, foremen, deputy foremen, and operators of the maintenance section. The rating scale should be used as a reference to determine the score of frequency of occurrence, degree of severity, and change of detection.

2.2 Failure Mode and Effect Analysis (FMEA)

Failure Mode and Effect Analysis (FMEA) is a method for evaluating the possibility of failure of a system, design, process, or service which can be quantified for determining the priority of a possible solution (Risk Priority Number) [5]. FMEA encourages higher reliability and quality and improves security. This can also be used to assess and optimize a maintenance plan [6]. In this study, such method was used to identify the failures that occurred, including:

1. Damage level (severity) or how serious the damage to the process was
2. Frequency (occurrence) or how much interference could cause a failure
3. Detection level (detection) or how failures could be identified before happening [5]

In FMEA, the Risk Priority Number (RPN) represents the relationship between three variables that include Severity (S), Occurrence (O), and Detection actions [7]. The RPN provides guidance to determine potential failures and then provides suggested actions for design/process changes to the severity so that appearances are lower [8].

The steps taken were:

1. Identifying the machines used in the production process
2. Identifying some potential failure modes of the machine, the effect of failure modes on the machine, and the cause of the failure modes
3. Assessing failure modes on the machine for severity (S), occurrence (O), and detection (D)
4. Calculating the Risk Priority Number (RPN) using the equation [5]:

$$\text{RPN} = S \times O \times D \quad (1)$$

2.3 Logic Tree Analysis (LTA)

Logic Tree Analysis (LTA) was used to determine the consequences and give priority to each failure mode [9]. It is a qualitative process to categorize each failure mode by answering questions as follows [10]:

1. Evident: Does the operator know that in normal conditions there has been disruption in the system?
2. Safety: Does the failure mode cause safety problems?
3. Outage: Does the failure mode cause the machine to stop?

The problem category was divided into four consisting of [10]:

1. A category or safety problem: if failure mode caused safety disturbance to the operator or the environment
2. B category or outage problem: if failure mode resulted in system failure that could cause significant economic losses
3. C category or economic problem: if failure mode did not affect the safety or failure of the system, but it caused relatively small economic losses for repair
4. D category or hidden failure: if the failure mode was difficult to detect because it was hidden from the operator's vision

3. RESULT AND DISCUSSION

3.1 Result of Failure Mode and Effect Analysis (FMEA)

The results of this study are shown in Table 3.1 and Table 3.2 with Table 3.1 describing the function of the machine and Table 3.2 explaining the results of failure modes, effects, and causes of failure modes for each machine as well as the Risk Priority Number (RPN).

For the unigrator machine, the failure modes identified were a loose hammer tip, a broken end of the cutter, a non-balanced hammer rotation, and a broken hammer handlebar. These failure modes resulted from the components that have passed the service life and the material that was not good, making the components slip and enter the machine and cause a stop. In the cane unloading crane machine, the failure modes identified were a broken wheel bearing and a loose switch caused by less lubrication and excess loads making the crane unable to move. Meanwhile, in the cane table and cane carrier machines, the failure mode found was a loose split pin due to wear, causing the chain to break. In the intermediate carrier, the failure modes included a loose fastener bolt and overload because it was not welded and due to low vapor pressure that made the machine motor drive stop working. In the hydraulic pump, the installation was too tight causing damage to the rubber seal, so it could not pump maximally. Meanwhile, in the milling machine, failure modes were also identified because the turbine coupling and screw-bolt were broken and the roller was hollow. Such failures occurred because the material used was not good and the part was hit by a heavy object, leading to less optimal milking process.

Table 3.1 Function of Machine

Name of Machine	Description
Unigrator	Chopping sugar cane
Cane Unloading Crane	Lifts sugar cane from Lorry then move it to Cane Table
Cane Table	Set sugar cane placed and put sugar cane on Cane Carrier
Cane Carrier	Transport sugar cane from Cane Table to Milling Machine
Intermediate Carrier	Transport sugar cane pulp from one Milling Machine to the next
Hydraulic Pump	Put pressure on mill roll to be stable
Milling Machine I-V	Milking sugar cane

Table 3.2 Failure Modes, Effect and Cause, Risk Priority Number (RPN)

Name of Machine	Failure Mode	Effect	Cause	S	O	D	RPN
Unigrator	a loose hammer tip	Component can enter the milling machine and cause a stop	The components exceed the service life	5.8	2.3	4.1	55
	a broken end of the cutter	Component can enter the milling machine and cause a stop	The material used is not good	5.5	4.6	3.7	92
	a non-balance hammer rotation	Bearing components are damaged	Installation is done with a different hammer weight	3.7	2.6	3.3	32
	a broken hammer handlebar	Component can enter the milling machine and cause a stop	The components exceed the service life	5.7	4.3	3.5	86
	a broken laker wheel	Crane cannot move	Less lubrication	4.0	5.3	3.9	82
Cane Unloading Crane	a loose switch	Motor drive stops working	Electric panels lift high loads	4.3	4.8	3.6	74
Cane Table	a loose split pen	Chain is broken	Wear	3.5	3.7	3.6	47
Cane Carrier	a loose split pen	Chain is broken	Wear	4.2	3.4	3.8	54
Intermediate Carrier	a loose fastener bolt	Component can enter the milling machine and cause a stop	Welding is not done	4.6	3.1	3.7	52
	overload	Motor drive stops working	Vapor pressure is low	5.9	2.6	3.8	67
Hydraulic Pump	sheal rubber destroyed	Pressure is not achieved so it cannot pump maximally	Rubber installation is too tight	3.4	4.3	4.3	64
Milling Machine I-V	the turbine coupling is broken	Gear box cannot be connected	The material used is not good	6.3	3.5	3.5	77
	the screw-bolt is broken	Component can enter the milling machine and cause a stop	The material used is not good	6.4	5.7	3.7	135
	the roller is hollow	Milking process is less than optimal	Heavy object hits	3.2	5.6	3.9	70

From the data in Table 3.2, an assessment of FMEA variables was made containing the severity, occurrence, and detection of failure modes in each machine followed by calculation of the value of Risk Priority Number (RPN).

The highest RPN value is obtained when the severity level of the failure modes has a significant effect in which the machine experiences downtime for the repair process. The high frequency of occurrence and high detection rate on the machine because of the failure mode that occurs can be detected by the machine operator with eyesight.

In contrast, a low RPN value is obtained because the severity of the failure modes has a mild effect which does not interfere with the production process and the machine continues to operate. The level of occurrence with a slight frequency and a high detection rate for damage due to failure mode can be detected by the operator through sound and vibration.

3.2 Result of Logic Tree Analysis (LTA)

Table 3.3 Logic Tree Analysis

Name of Machine	Failure Mode	Evident?	Safety?	Outage?	Category
Unigrator	a loose hammer tip	Yes	No	Yes	B
	a broken end of the cutter	Yes	Yes	Yes	B
	a non-balance hammer rotation	Yes	Yes	No	C
	a broken hammer handlebar	Yes	Yes	Yes	B
Cane Unloading Crane	a broken laker wheel	Yes	No	No	C
Cane Table	a loose switch		Yes	No	A and C
Cane Carrier	a loose split pen	Yes	Yes	No	C
Intermediate Carrier	a loose split pen	Yes	Yes	No	C
Hydraulic Pump	a loose fastener bolt	Yes	Yes	Yes	B
	overload	Yes	No	Yes	B
Milling Machine I-V	sheal rubber destroyed	Yes	No	No	C
	the turbine coupling is broken	Yes	No	Yes	B
	the screw-bolt is broken	Yes	Yes	Yes	B
	the roller is hollow	Yes	No	No	C

The classification of failure modes using LTA method was conducted by answering 3 questions in Table 3.3. The failure mode included in the A category was a loose switch, which is a safety problem. This damage can be identified by the operator when the machine is operating. If this damage is not repaired immediately, it can cause short-circuiting which can threaten the safety and work environment.

The failure modes of B category were a loose hammer tip, a broken end of the cutter, a broken hammer handlebar, a loose fastener bolt, a broken screw-bolt, and overload, categorized as an outage problem. Such damage causes the engine to stop operating for 30-60 minutes because at the time of repairs the operator looks for the broken components that enter the engine. The failure modes in C category consisted of non-balanced hammer rotation, broken wheel bearing, loose split pen, destroyed rubber

seal, hollow roller, and loose switch. They do not cause the engine to stop since repairs can be done when the engine is running, so it does not interfere with the sugar production process.

3.3 Preventive Maintenance

Preventive maintenance is performed by carrying out inspections and actions that have been planned for the implementation time to restore the operating function of a machine to avoid severe damage to the engine [11].

Based on the analysis from Table 3.2, it is acknowledged that damage occurred because the component life exceeded the limit, and there was less lubrication, less cleanliness after use, and wear. From this, improvements should be made by checking conditions, scheduling component replacement, giving lubrication, and cleaning regularly. The condition of the machine should be checked every day, lubrication with oil is done once a week, component replacement is carried out after 1 milling season, and cleaning and maintenance of the machine should be performed weekly and monthly.

Table 3.4 Preventive Maintenance

Name of Machine	Failure Mode	LTA Category	Preventive Maintenance
Unigrator	a loose hammer tip	B	Checking the condition regularly, replacing components after one milling season (6 months)
	a broken end of the cutter	B	Checking defects during installation, checking the condition regularly, replacing components after two milling season (1 year)
	a non-balance hammer rotation	C	Installing with the same weight (17kg-19kg per hammer handlebar), checking the condition regularly
	a broken hammer handlebar	B	Checking the condition regularly, replacing bolts before they wear (4 to 5 months)
	a broken laker wheel	C	Giving regular lubrication with oil and Vaseline, replacing components after two milling season (1 year)
Cane Unloading Crane	a loose switch	A and C	Load lifting according to capacity (5, 10 and 16 tons), cleaning of dirt
Cane Table	a loose split pen	C	Checking the condition regularly, replacing components after one milling season (6 months)
Cane Carrier	a loose split pen	C	Checking the condition regularly, replacing components after one milling season (6 months)
Intermediate Carrier	a loose fastener bolt	B	Welding bolts during installation, checking the condition regularly
	overload	B	Checking vapor pressure regularly, maintaining vapor supply for a stable pressure
Hydraulic Pump	sheal rubber destroyed	C	Checking defects during installation, replacing sheal rubber after one milling seasons (6 months)
	the turbine coupling is broken	B	Checking defects during installation, checking the condition regularly, replacing components after two milling season (1 year)
Milling Machine I-V	the screw-bolt is broken	B	Checking the condition regularly, replacing bolts before they wear (4 to 5 months)
	the roller is hollow	C	Controlling heavy objects from grinding

4. CONCLUSION

Based on the results of the processing and discussion carried out, it can be concluded as follows:

The study using Failure Mode and Effect Analysis (FMEA) obtained such failure modes as broken screw-bolt, broken end of the cutter, broken hammer handlebar, broken wheel bearing, broken turbine

coupling, loose switch, hollow roller, overload, destroyed rubber seal, loose hammer tip, loose split pen, loose fastener bolt, loose split pen, and non-balanced hammer rotation.

The classification of failure modes using Logic Tree Analysis (LTA) in each machine found failure modes of A category (safety problem) that included loose switch, failure modes of B category (outage problem) including loose hammer tip, broken end of the cutter, broken hammer handlebar, loose fastener bolt, broken screw-bolt, and overload, and failure modes of C category (economic problem) consisting of non-balanced hammer rotation, broken wheel bearing, loose split pen, destroyed rubber seal, hollow roller, and loose switch.

The following preventive maintenance should be carried out to prevent machine failure based on the LTA category. For the A category (safety problem), it is recommended to operate the machine in accordance with the Standard Operating Procedure (SOP), for the B category (outage problem), recommendation includes regular machine inspection and preparation of parts for replacement of damaged components, and for the C category (economic problem), installation of appropriate components, lubrication, and cleaning of dirt is recommended.

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