Developing Autonomous Maintenance through FMEA-RCM Models to Reduce % Machine Breakdown in Food and Beverages Industry

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Abstract: In order to reduce % of breakdown (9 to 16% in semester 1 of 2018) in filling machine type A, Nutrifood Cibitung factory implemented Autonomous Maintenance (AM). Which, operator involves in the maintenance process of the production machine. AM also supports and emphasizes in the proactive-preventive maintenance in the Engineering department. In this research, autonomous maintenance task was developed using Failure Mode Effect Analysis (FMEA) and Reliability Centered Maintenance (RCM) on each part of the machine to determine every failure possibility and the root causes. Autonomous maintenance is developed through an understanding of existing problems or a history of machine breakdown and minimizing the source of deteroriation (Sara, 2015). FMEA-RCM is used to determine every failure possibility and the root causes of the failure. This failure possibility was prevented through the certain task (when, where & how) that is conducted in autonomous maintenance by operator. Scope of the task is limited to 4 tasks: Cleaning, Lubrication, Inspection, and Tightening (CILT) in filling machine type A of Nutrifood Cibitung Factory. Implementation of autonomous maintenance that was developed through FMEA-RCM framework has reduced 40-60% breakdown level from semester 1 of 2018 in filling machine type A. This maintenance activity provides initial detection of a failure in the machine which triggers the maintenance team to fix the problem before getting worse. Autonomous Maintenance also standardizes and increases operator skills in doing maintenance of their machine.

1 INTRODUCTION

Autonomous maintenance is one of the foundations of Total Productive Maintenance (TPM), which its aimed to involve production in maintaining their own asset. Total Productive Maintenance (TPM) was developed at Japanese car industy in the 1970s, it was firstly introduced and successfully being implemented in Nippon Denso Co., Ltd. Total means involvement of all employees at all levels of the organisation, productive means effective utilization of all resources and maintenance means keeping the Man-Machine-Material system in optimum condition (Owen, 2011).

Autonomous maintenance (AM) is confined to 4 major tasks: Cleaning, Lubrication, Inspection, and Tightening (Mugwindiri, 2013). Autonomous maintenance provides new habits that are: by clean machine's part, we start to inspect, this inspection will lead us to get preliminary detection of deterioration, which this detection trigger an early correction to the part of machine before it is getting worse. Which is carried out by operators in a certain sequence of time. Development of AM utilised Failure Mode Effect Analysis (FMEA) model, which is used to determine the type of failure that can occur in the machine's part.

FMEA was introduced by Ford Motor Company to the automotive industry for safety and regulatory consideration in the late 1970s. It also used to improve production and design. In the 1980s, the automotive industry began implementing FMEA by standardizing the structure and methods through the Automotive Industry Action Group (Carl, 2016). It continues to be associated by many with reliability engineering. It analyses potential effects caused by system elements ceasing to behave as intended (Carl, 2016).

This model requires potential causes, effect analysis, and also action needed. Focus Group discussion being held between production and engineering department to develop FMEA. Every potential cause in part weather it comes from operational activity or lifetime is cleaned, inspected,

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lubricated or tightened based on the history of breakdown and also the possibility of operational activity interfere with the parts.

Reliability – Centered Maintenance (RCM) was firstly developed by airlines in 1967 through tree logic. This tree logic then formed the basis for the design of the initial matintenance program for the Boeing 747. In the early '70s, this worked being used by the Office of the Secretary of Defense, the Naval Air Systems Command, the Air Force, dan the Army.

Reliable Center Maintenance (RCM) first use to describe a process used to determine the optimum maintenance requirements for aircraft. There are six concepts that support RCM. 1) an understanding that the vast majority of failures are not necessarily linked to the age of the asset. 2) changing from efforts to predict life expectancies to trying to manage the process of failure. 3) an understanding of the difference between the requirements of assets from a user perspective, and the design reliability of the asset 4) an understanding of the importance of managing assets on condition (often referred to as condition monitoring, condition based maintenance and predictive maintenance). 5) an understanding of four basic routine maintenance tasks. 6) linking levels of tolerable risk to maintenance strategy development (Nowlan, 1978)

In order to reduce breakdown level in our Sweetener Line, PT Nutrifood Indonesia started to implementing autonomous maintenance program trough FMEA-RCM model to minimize potential deterioration or failure. This project aimed to reduce % breakdown in Sweetener filling line. Which in 2017, we were facing on average from 4 machines 11% breakdown level in sweetener filling line.

2 THEORITCAL BACKGROUND

In terms of developing autonomous maintenance tasks, which belongs to Total Productive Maintenance, PT Nutrifood Indonesia using a tool that was used in Realibity Centered Maintenance. The tool was a failure mode effect analysis (FMEA).

2.1 Autonomous Maintenance

Autonomous maintenance is one of the pillars in Total Productive Maintenance (TPM) (Owen, 2011) :

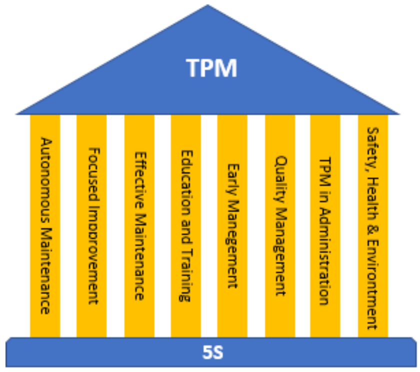

Figure 1: Pillar of TPM .

Which autonomous maintenance is restricted into 4 major tasks :

a. Cleaning
b. Inspection
c. Lubrication
d. Thightening

The value that was brought by AM was (Day, 2004):

Table 1: Step Process of AM from ANADIGICS.

Step	Activity
Step Zero	Preparation
Step One	Clean to inspect, inspect to detect
Step Two	Detect to correct
Step Three	Correct to perfect

2.2 FMEA

Failure Mode and Effects Analysis is a method designed to:

a. Identify and fully understand potential failure modes and their causes, and the effects of failure on the system or end users, for a given product or process.
b. Assess the risk associated with the identified failure modes, effects and causes, and prioritize issues for corrective action.
c. Identify and carry out corrective actions to address the most serious concerns.

An FMEA should be the guide to the development of a complete set of actions that will reduce the risk associated with the system, subsystem, and component or manufacturing/assembly process to an acceptable level (Carl, 2016).

Below is the example of FMEA that is used in this project :

Table 2: FMEA form for analysis.

Machine/Sub-machine	Function	Functional Failure	Failure Mode	Failure Effect

a. A "Machine/Sub-machine" is the focus item of the FMEA project
b. A "function" is a standard or minimum requirement of the machine/submachine is intended to achieve.
c. A "functional failure" is a failure to reach the minimum target or standard that has been set.
d. A "failure mode" is a potential failure or deterioration that causing functional failure. This can be a single potential failure, or more.
e. An "effect" is the consequence of the failure on machine/sub-machine.

2.3 RCM

Rather than focusing immediately on subsystems or equipment and asking, "What preventive maintenance can be done?", RCM starts from the top by (Catola, 1983):

a. Partitioning the ships into systems and subsystems that require analysis;
b. Identifying additional functionally significant items;
c. Determining the maintenance requirements (tasks) for each significant item based on analysis of its functions, both evident and hidden, and its dominant failure modes;
d. Determining when, how, and by whom each task will be done;
e. Identifying needs for design change when safety is threatened by a failure for which there is no applicable and effective task; and
f. Using information obtained from operations and appropriate analytical techniques to adjust these intervals and revise task content.

Which, partitioning the ships into systems and subsystem is depicted in FMEA by Machine and Submachine. The function of machine and submachine was described also in FMEA.

3 METHODS

Development and implementation of autonomous maintenance were devided into 4 step processes :

a. AM Initial Preparation
    - AM team preparation
    - AM time frame
    - Machine preparation
b. AM Preparation
    - Development FMEA-RCM
    - Determine autonomous standard (CILT)
c. Execution Phase
    - Initial deep cleaning
    - Training for implementation
    - Monitoring
d. Evaluation Phase
    - Results were gained from AM

The end result was evaluated by comparing breakdown level in filling machine type A in semester 1 of 2018 with semester 2 of 2018.

% Breakdown level itself was calculated trough :

$$\% \text{ breakdown} = \frac{\textit{Repair time (minute)}}{\textit{Planned Production Time (minute)}} \quad (1)$$

4 DISCUSSION

4.1 AM Initial Preparation

In this step process, mapping the program was conducted. Team selection was delivered by involving 2 both production and engineering team.

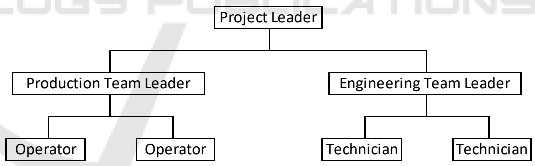

Figure 2: AM Project Team.

The development project involves employees to the lowest level: operators, technicians were contributed to completing FMEA. Concerns that been happened on the floor were brought to the FMEA scheme. So that FMEA could be generated to capture all of the possibilities of failure.

The time frame was arranged to finish FMEA and also develop cleaning, inspection, lubrication and tightening task in the autonomous task. It is also covering the time in implementation of autonomous maintenance in the selected machine.

The pilot plant was choosen from table top of filling machine that suffering from a breakdown.

Table 3: Top 5 % Breakdwon in Filling Machine.

No	Machine	% Breakdown
1	Machine A - 1	16%
2	Machine A - 3	10%
3	Machine A - 2	9%
4	Machine A - 4	9%
5	Machine B - 5	4%

Machine Type A was choosen to be the pilot project, and the operators involved in the development of FMEA was delegated to run this machine type Auring implementation step.

4.2 AM Preparation

Machine Type A was devided into several submachines. This submachine is representing the main function in a group of part machines. Grouping helps to determine the function of machine specificaly. Group of the machine led operators and technician to frame the position of parts and also build the potential failure in detail.

Cleaning, Inspection, Lubrication and Tightening were conducted through detail FMEA. CILT was the preventive action that is assigned to maintain zero failure or deterioration. Every part in the sub machine was discussed and analyzed, through the history of a breakdown in machine type A and in a similar type of part in another machine.

Table 4: Autonomous Maintenance Task in Machine Type A.

Koding	No	Proposed Tasks	Interval	Alat Ukur/Tools	Standard	Checklist	Catatan
II	Tasks-Dosing Unit						
Cleaning	1	Pengelapan bearing idle pin	Akhir Shift	Kanebo kuning	Tidak ada deposit (debu/produk/oli lumer) & tidak aus/karat		
	2	Pembersihan locknut adjustment	Akhir Shift	Kanebo merah & Compressed Air	Tidak ada deposit (debu/produk/oli lumer)		
	3	Pembersihan jalur rod funnel	Akhir Shift	Majun dan Penetrate FG	Tidak ada deposit (debu/produk) & tidak aus/karat		
	4	Pembersihan spring rod funnel	Akhir Shift	Majun dan Penetrate FG	Tidak ada deposit (debu/produk) & tidak aus/karat		
	5	Pembersihan bushing/bearing penggerak rod funnel	Akhir Shift	Majun dan Penetrate FG	Tidak ada deposit (debu/produk) & tidak aus/karat		
	6	Pencucian cup doser	Akhir Shift	Visual check	Spring harus dilepas dan dilap		

The unique code also is used to guide operators doing the task. The code was provided in the machine and in AM reporting paper, visualy can help operators know what they have to do.

Figure 3: Visual Management in Machine Type A.

The code is representing : main tasks (cleaning / inspection / lubrication / tightening), sequence (daily / 3 weeks or every 500 hours of running), Submachine and the number of tasks.

4.3 AM Execution

At this phase, operators were educated on how to do cleaning, inspection, lubrication and tightening properly. This activity was delivered by Engineering teams. Operators and Technicians also did an initial deep cleaning to all parts in machine type A.

This initial deep cleaning was aimed to restore the condition of the machine as it was firstly coming. Initial deep cleaning help us to determine a preeliminary judgement on the condition of the machine, it helped us restore part that had been broken and replace it with the good one. Then, the operator just keeps maintaining machine type A as it has been totaly cleaned.

After the normalized condition of the machine, operators were monitored daily, 3 weekly to ensure that all of the items in the task being conducted. It also helps us to communicate initial finding related to abnormalities that happened to the machine type A to the Engineering team.

4.4 AM Evaluation

During the AM process, production could reduce trapping sachet that happened due to the cleaning issue. Which dust interrupted the sealing process in a sachet. AM provide regullar cleaning in all line that being passed by sachet. Regular cleaning and lubrication ensure every rotation in bearing, motors and chain work without problems.

Breakdown level could be decreased by 40 % – 60 % from the previous period (Semester 1 – 2018). We also reduce non added value activity such as: cleaning of the funnel at the end of a shift can be lowered after 3 days of usage.

Table 5: % Breakdwon in Filling Machine Type A after.

No	Machine	% Breakdown	
		Before	After
1	Machine A - 1	16%	8%
2	Machine A - 3	10%	4%
3	Machine A - 2	9%	3%
4	Machine A - 4	9%	2%

There is some deviation in each machine, which machine A has the biggest gap than other machines. This gap was happened due to the part that was needed should be delivered from Europe. This machine took a long period of time to change this special part.

Cleaning program provides minimum interruption of dust or polluter enters the part of the machine (for example: bearing, or heater). Which, could help the machine perform better. Inspection helped us to find an initial abnomalities in the machine, so that we could solve the machine's problem faster before it affected another part (make the breakdown worst). Regular lubrication keeps the part in machine run smoothly as the setting of the parameter that has been set in HMI. Tightening keeps all the mechanical part stick to the initial places, so as the machine run there will be no shifting on it.

Autonomous maintenance (CILT) that was developed through FMEA-RCM processes could be one of the solutions to boost machine peformance in the food and beverage industry. FMEA-RCM processes clearly gave us a deep analysis and helped us to provide specific and relatively precise action to be done in autonomous maintenance by operator. It combined historical data of machine breakdown and also analysis of failure probability in the parts of the machine. It is also standardizes how operator maintains their machine and share the responsibility to maintain a machine between technician and operator.

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6 CONCLUSIONS

Autonomous maintenance provides benefits to our production line. Which help us to :

a. Reduce breakdown level in filling machine Type A in average from 11% to 4.2%
b. Reducing non added value activity (cleaning funnel)
c. Sharing responsibilities in maintaining machine with Engineering
d. Provide new habits and development to operator skills : cleaning to inspect, inspect to detect, detect to correct, correct to perfect
e. FMEA-RCM processes can be a usefull tool to develop autonomous task in the food and beverage industry. It combained data of machine breakdown and also analysis of failure probability in the parts of the machine.

This project will be copied to another type of machines in production. The flow process will be conducted as it had been proven from this project.

ACKNOWLEDGEMENTS

We realize that AM implementations take a lot of effort. In addition to developing a good analysis, we are facing a challenge that is related to changing operator habit. Making sure that monitoring and consistency in doing every single task of AM are conducted also take a lot of time (a lot of task and lot of machine). Awareness on the top management, supervisory level, and operators become the key success to implement AM to reduce machine breakdown. And continously upgrade AM task related to the history of the machine after implementation and eliminating unnecessary tasks.

REFERENCES

Carl S. Carlson, 2016. *Understanding and Applying the Fundamentals of FMEAs*. Reliability and Maintainability Symposium.

Catola, S., G., 1983. *Reliability-Centered Maintenance Handbook.* Direction of Commander, Naval Sea Systems Command.

Chen, C. 2013. A developed autonomous preventive maintenance programme using RCA and FMEA, *International Journal of Production Research*. Taylor & Francis

Day, J., Troy, D., Heller, D., 2004. *The Implementation of Autonomous Maintenance (Part 1 in a series of the Total Productive Manufacturing Experience)*. CSMANTECH.

Nowlan, F. Stanley, and Howard F. Heap. *Reliability-Centered Maintenance. Report Number AD-A066579*. United States Department of Defense. 1978. Archived from the original (PDF) on 2013-08-01.

Miranda, S. F., Lopes, I. S. 2015. *Development of Autonomous Maintenance in a Furniture Company*. World Congress on Engineering. Vol. II

Mugwindiri, K., Mbohwa, C., 2013. *Availability Performance Improvement by Using Autonomous Maintenance - The Case of a Developing Country, Zimbabwe.* Vol I. World Congress on Engineering.

Owen, C., 2011. *Total Productive Maintenance.* Retrieved from https://www.industryforum.co.uk