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ANALYSIS OF MEASUREMENT EQUIPMENT EFFECTIVENESS INJECTION MACHINE GMA WITH SIX BIG LOSSES AND FMEA IN MANUFACTURE

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Abstract

This study aims to analyze Overall Equipment Effectiveness (OEE) of the injection machine GMA on solar water heater fabrication, using measurements of Six Big Losses and FMEA. Fishbone diagrams and FMEA are used to find the root cause of the problem and give priority actions to solve the problem. This type of research uses descriptive quantitative methods with secondary data from losses. For population data that is data collection using GMA machines in the injection process, while data samples use data from April - October 2019. The result of the study show that Overall Equipment Effectiveness (OEE) has not met the target determined by company. The biggest losses that affect the low effectiveness is Reduced speed losses. These losses are generally caused by method and human factors so that the proposed corrective action is the implementation of autonomous maintenance, improve Maintenance Management System (MMS) document, training for operator and critical spare part management accordance with the Total Productive Maintenance concept.

Key words: OEE, Six Big Losses, Reduce speed losses, FMEA.

I. Introduction

1.1. Background

The current condition of the industrial at this time, making manufacturing companies must compete fiercely to seize their market share by producing quality products at competitive prices.

To achieve a competitive selling price is determined by the effectiveness and efficiency of the production operational system so that it can be said productive in the business process. As an effort to increase productivity is to evaluate the performance of production facilities in the company...

Evaluation of the performance of production facilities is generally known as maintenance activities, which have the aim to facilitate the process so that production continues to run, and ensure the flow of production activities do not experience disturbances that cause not running production activities. Therefore maintenance activities in production management are very important and play a significant role, because they will be related to whether or not the activities of the production process, production time, quality, scheduling and production volume (Sutawijaya, 2019).

Basically, machine maintenance activities are also related to preventive maintenance, known as preventive maintenance, which is a plan that requires routine inspection, maintenance and keeps the facility in good condition so that no damage occurs in the future (Heizer and Render, 2001: 704).

Equipment management methods in the manufacturing industry today, the concept of Total Productive Maintenance (TPM) has been widely used in achieving machine effectiveness with an Overal Equipment Effectiveness (OEE) as an indicator. From a review of previous research it is known that the application of the TPM concept can reduce the frequency and duration of engine downtime. After carrying out routine maintenance activities, the technician can test other parts of the machine that might need to be replaced. Replacing parts during scheduled maintenance periods is easier and faster than dealing with machine failures during the production process. Maintenance is carried out on a schedule that balances with the maintenance program with the aim of preventing the risk and cost of machine failure.

Actually, company has planned the maintenance of production machinery and made repairs to the damage found. However, it is often not carried out in more detailed analysis of the problems that occur so that the corrective action taken is not in accordance with the root of the problem, so the same problem repeatedly arises. This causes deficiencies that can interfere with or hinder the achievement of production levels as well as disrupt the fulfillment of delivery requests to customers.

Table 1.1 Overall Equipment Effectiveness (OEE) injection machine GMA H-40

Month	Availability Ratio (%)	Performance Efficiency (%)	Quality Rate (%)	OEE (%)
April 2019	95,1 %	50,9 %	98,99 %	47,89 %
May 2019	91,8 %	35,5 %	98,83 %	32,25 %
June 2019	94 %	20,0 %	97,18 %	18,35 %
July 2019	95%	19,3 %	98,43 %	18,06 %
August' 2019	95,1 %	39,0 %	98,89 %	36,74 %
Sept' 2019	94,9 %	66,6 %	99,08 %	62,65 %
Oct' 2019	94,9 %	26,6 %	98,91 %	25,00 %
Average	**94,4 %**	**37 %**	**98,62 %**	**34,42 %**

(Source: Research data, 2019)

PT. XZ, located in Bogor is a company engaged in the design, fabrication and distribution business of Solar Water Heaters. To meet the demands of the retail market, good planning is needed on the company's operations. Problems occur in the Production section. Can be seen from the data presented, that there is a problem in the value of OEE or the effectiveness of the GMA injection machine..

Based on the data presented in table 1 regarding the OEE value of the GMA injection machine, it tells us that the OEE value does not meet the World Class Standard with the following criteria: Availability Rate> 90%, Performance Efficiency> 95%, Quality Rate> 99% and OEE its greater than 85%.

Variables that influence the achievement of OEE values are Availability with an average achievement of 94.4%, Performance values with an average achievement of 37% and Quality rate values with an average achievement of 98.62%.

The three variables that have the lowest achievement is the Performance value, so this is a problem in the production operational process which has an impact on not achieving the Solar Water Heater production target.

To solve the above problem, minimizing the level of Performance losses is very important. The selection of the right analytical method to trace the root of the problem according to existing data needs to be done by looking at previous research so that the root of the problem can be found appropriately.

Therefore, it is expected that with this research can provide suggestions or recommendations for improvements that are useful for management so that the machine can operate more efficiently in the future

Refer to the above phenomenon, researcher want to use the measurement of Six big losses, Fishbone diagrams and FMEA as analysis tools.

Based on the background description, it is necessary to do research with the title: "Analysis of Measurement Equipment Effectiveness Injection Machine GMA with Six Big Losses and FMEA in Manufacture."

1.2. Research Purposes

The objectives to be achieved in this research are:

1. Knowing the cause of the OEE value of the GMA H-40 machine is not achieved by making more detailed measurements of the Six big losses factor and through FMEA analysis.
2. To obtain a solution to the implementation of the operating system and maintenance of the GMA H-40 machine by providing suggestions for repairing the main problem with the concept approach of applying the appropriate TPM pillars.

II. Theoretical Review

2.1. Overall Equipment Effectiveness (OEE)

Overall Equipment Effectiveness is a critical measurement carried out in the application of TPM to evaluate the ability of a machine/equipment in a production system. OEE consists of three main components, namely: availability, performance and quality (Borris, 2010).

The three main ratios must be known first, then multiplying the three ratios will get its OEE value.

One of the main objectives of knowing OEE is to reduce or eliminate the so-called six major losses that are the most common causes of loss of efficiency. Six big losses are known as downtime losses which are useful for calculating engine availability (Hapsari, et al, 2012).

2.1.1. Six Big Losses

Denso (2006) states that in the calculation of OEE can be traced into 6 major losses (the six big losses) cause production equipment is not operating normally, namely:

1. Breakdown losses (Downtime losses), It is engine failure which is usually more than 10 minutes. Breakdown time will be recorded until the production machine can operate again in producing good product units. This can be damage of tooling, jig, unplanned maintenance, general breakdowns or equipment failures.
2. Setup and Adjustment losses (Downtime losses), is the time it takes for the machine to warm up or if there is an exchange of models or products. Included in this group are

setup/changeover, material shortages, operator shortages, major adjustments and warm up time. In essence, these losses are those that arise because of the time used for setup or changeover.

3. Idling & minor stop losses (Speed losses), is the cessation of the machine in a short time (generally under 5 minutes) but the frequency of occurrence is high. This frequent short stop causes the resulting output to be reduced. Among them are obstructed product flows, component jams, misfeed, sensor blocked, delivery blocked and cleaning. An indicator of this problem is that maintenance personnel are not needed for repairs.
4. Reduced speed losses (Speed losses), Included in this loss are rough running, under nameplate capacity, under design capacity, equipment wear and operator inefficiency. The problem arises because the speed of the process is outside the tolerance limits of machine capacity.
5. Rework losses (Quality losses), included in this group are rework and in process damage, ie rejects that occur during the production process.
6. Yield / Scrap losses (Quality losses), It is a reject that occur but cannot be reworked, including in this loss are rejects that occur during the warm-up process and can also be caused by a machine set up error.

From the six losses above, it can be concluded that there are three types of losses associated with the production process that must be anticipated, i.e.:

1. Downtime losses which influence Availability rate,
2. Speed losses which influence Performance rate, and
3. Quality losses which influence Quality rate.

2.2. Fishbone Diagram

The TPM implementation team must analyze each tool and make the necessary repairs (Sharma, 2011). Fishbone diagrams are analytical tools that can be used to determine the root cause of a problem (Hamzah, 2010).

The use of Fishbone diagrams can be done with the following steps:

1) Get an agreement on the problem that occurred and express the problem as a question (problem question).
2) Awaken a set of possible causes by using reasoning techniques or by forming team members who have ideas relating to the problem being faced.
3) Draw a diagram with the problem questions placed on the right side (forming the fish head) with the main categories such as humans, machines, methods, raw materials and the environment. The main category is placed on the main branch (forming large bones of fish) where this main category can be changed as needed.
4) Assign each cause in the appropriate main category by placing it in the appropriate sub causes.
5) For every possible cause, ask why? To find the root cause, then list the roots in the branches that correspond to the main categories of forming small fish bones.
6) Interpret the diagram by looking at the causes that emerge repeatedly, then get agreement through consensus on these causes.

7) Determine the results of the analysis using these cause and effect diagrams by developing and implementing corrective actions and monitoring results to ensure that the corrective actions taken are effective in removing the root causes of the problem at hand.

2.3. Failure Mode and Effect Analysis

FMEA is a set of instructions, a process and a form for identifying and prioritizing potential problems (failure). By basing their activities on FMEA, the improvement team or process owner can focus energy and resources on prevention, monitoring and response plans that are most likely to produce results (Pande 2003: 402).

FMEA can also be said to be an analytical technique used as a tool to identify, prioritize and eliminate potential damage from a system, design or process.

In general, FMEA can identify three things, namely the potential cause of failure of the process, the effect of the failure and the level of criticality of the effect of failure on the function of the process or product.

Some of the terms contained in the use of FMEA are:

1. Item atau Process step: components of the system/tool that we analyze or process steps.
2. Potential Failure Mode: failure mode that often occurs.
3. Potential Effect(s) of Failure: the effect or impact caused if the component fails as stated in the potential failure mode.
4. Severity (Sev): quantification or scale that shows how serious the consequences are if a potential failure mode occurs.
5. Potential cause(s) of Failure: For whatever reasons that cause failure.
6. Occurrence (Occ): a scale that shows the likelihood and potential of the cause of failure to lead to failure.
7. Current control / Fault detection: Shows what methods have been applied to anticipate these failures.
8. Detection (Det): a scale that indicates the degree of likelihood of passing the cause of failure from the control that was created.
9. Risk Priority Number (RPN): is the result of multiplication of weights from Severity, Occurrence and Detection.
10. Action Priority (AP): proposed priority corrective actions to reduce the risk of failure by looking at a combination of SOD values.

2.4. Framework

The framework used in this study can be seen in Figure 2.1 as follows.

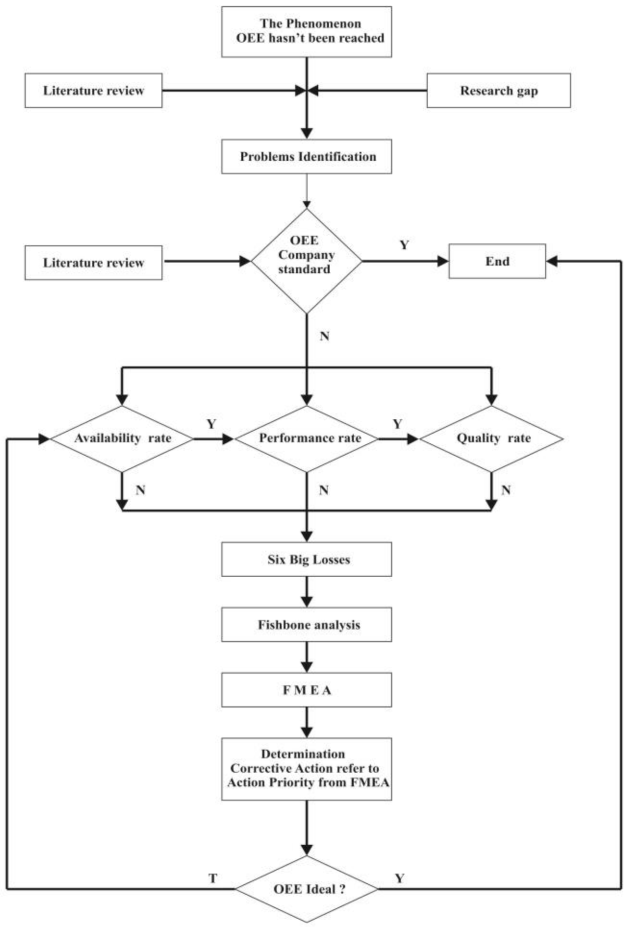

Figure 2.1 Research Framework
(Source: Author's documentation, 2019)

III. Research Methods

3.1. Types of Research

The method used in this research is descriptive quantitative method. The quantitative approach rests on what is called structural functionalism, realism, positivism, behaviorism and empiricism which in essence emphasizes concrete matters, empirical tests and real facts. Quantitative research aims to test theories, build facts, show relationships between variables, provide statistical descriptions, estimate and predict the results (Sarwono, 2009).

The descriptive definition is the research design chosen according to the research objectives. Descriptive research is research that seeks to describe a phenomenon, event, event that is happening at the present time (Soendari, 2012).

This method was chosen because it is in accordance with the objectives of the research to be achieved, which wants to get suggestions for improvement of a concrete phenomenon by testing the theory and building facts.

3.2. Operational Definition and Variable Measurement

According to Sugiyono (2015: 38), the research variable is an attribute or nature or value of people, objects or activities that have certain variations that are determined by researchers to be studied and drawn conclusions. The research variable in this case Overall Equipment Effectiveness (OEE).

As a measurement tool, OEE measures how effective the equipment is used by identifying constraints and their impact on OEE. Effectiveness is measured by multiplying the Availability ratio, Performance ratio and Product quality ratio produced.

Six major losses commonly referred to as Six Big Losses on equipment or machines are the key metrics of OEE as a research dimension: Breakdown, Setup, Reduce Speed, Minor stop, Defect and Scrap losses. As for the indicators include operating time, actual output and product compliance with specifications.

3.3. Population and Sample

Population is a generalization area that consists of objects or subjects that become certain qualities and characteristics determined by researchers to be studied and then drawn conclusions (Sugiyono, 2015: 80). The sample is part or representative of the population studied (Arikunto, 2010: 174). The sample is part of the number and characteristics possessed by the population (Sugiyono, 2015: 81).

For population data that is a collection of data from activities in the process of injection on the GMA H-40 machine with samples from machine use data from April - October 2019.

3.4. Method for Data Collecting

3.4.1. Data Collecting Technique

Data collection techniques used to obtain data through interviews, observation and literature study.

3.4.2. Data types and Sources

Data sources come from internal sources of the company. While the type of data used is secondary data in the form of operating time, downtime data, reject data at the company where the research was conducted.

3.5. Data Analysis Method

After all the necessary data has been obtained, the data analysis will then be performed, i.e.:

1. Identify the data downtime, availability rate, performance rate and quality rate in detail.
2. Identify the dominant factors causing OEE values not yet achieved by calculating of Six Big Losses, analysis fishbone dan FMEA.

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IV. Research Results and Discussion

4.1 Calculation of Six Big Losses

Six Big Losses calculations show the results shown in Table 4.1. There are still many losses, making the writer have to sort out the data to find priority losses that need to be followed up for further analysis. To do this sorting, an analysis using the Pareto principle is used.

From the table it can be seen that the factor that has the largest percentage of losses according to the Pareto principle is the Reduce Speed Losses of 88.88%, causing the Performance rate to be low. And to find out the details of the causes of losses that occur further analysis with Fishbone and Failure Mode & Effect Analysis (FMEA).

Table 4.1 Six Big Losses Percentage

No	Six Big Losses Category	Total time losses (hours)	Percentage (%)	Cumulative (%)
1	Reduced speed losses	638,8	88,88 %	88,88 %
2	Setup and adjustment losses	35,75	4,97 %	93,85 %
3	Breakdown losses	23,7	3,30 %	97,15 %
4	Idling and minor stop losses	16	2,23 %	99,38 %
5	Scrap losses	3,25	0,45 %	99,83 %
6	Rework losses	1,25	0,17 %	100 %
	Total	718, 75	100%	

(Source: Data Processing Results, 2019)

4.2 Fishbone Analysis

From the analysis of OEE values, Six Big Losses and Pareto Diagrams, it is known that the biggest contributor to the low OEE value comes from the Speed losses category, namely Reduce Speed Losses.

After knowing the highest subsystem in producing losses, the next step is to identify the factors that cause the main causes using the Fishbone diagram.

Basically, Fishbone diagrams are used to present the causes of problems with the aim of identifying the cause of a problem, finding the cause and effect and taking corrective action, helping to investigate further factors to be analyzed using FMEA, and selecting the priority application of the Total Productive Maintenance pillar to solve the problem.

Based on the results of brainstorming that have been entered into the Fishbone diagram, the causes of the GMA H-40 engine experiencing a large Reduce Speed Losses can be seen in Figure 4.1. In the picture, it explains the factors that cause the review of aspects of Human, Material, Machine, Method, Measurement and Environment.

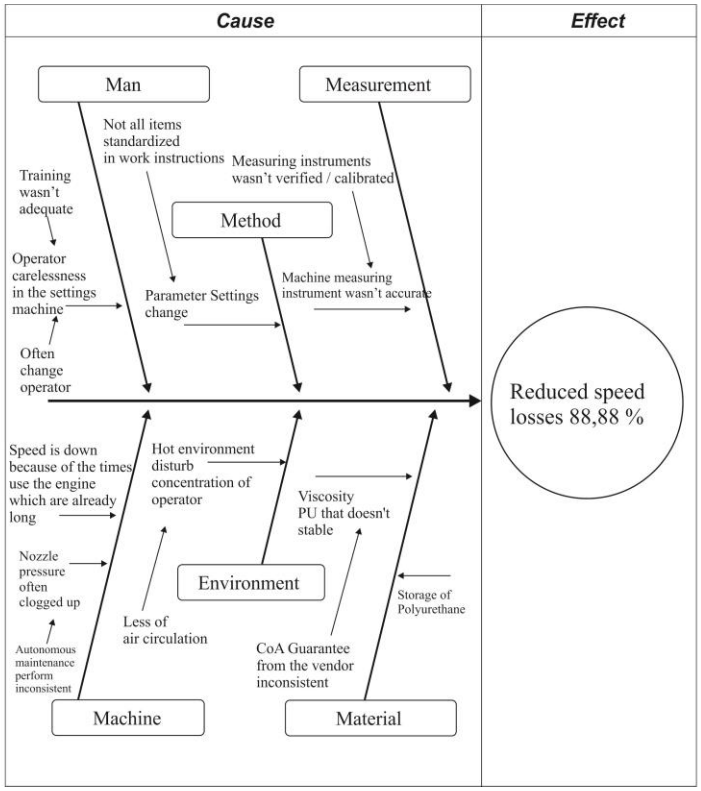

Figure 4.1 Fishbone diagram Reduced speed losses
(Source: Data Processing Results, 2019)

4.3. Failure Mode and Effect Analysis

After analyzing the cause effect with Fishbone diagram, the next is to identify the highest cause of failure using Failure Mode & Effect Analysis (FMEA) which can be seen in Table 4.2. The table only displays RPNs with values above 100.

Weighting the causes of potential failures, is done by multiplying the factors Severity (S), Occurrence (O) and Detection (D). This multiplication of S X O X D results in a Risk Priority Number (RPN) value that can be sorted from highest to lowest. Besides referring to the RPN factor, to review the accuracy of the follow-up recommendations, if the RPN values tend to be the same, it can be reviewed by looking at the combination of the S, O and D that can determine according to the Action Priority assessment table. The results of this FMEA analysis will determine the priority of planned improvements to improve engine efficiency. Based on the analysis of the Failure Mode & Effect Analysis (FMEA) that has been carried out and looking at the status of the Action Priority, it can be sorted the priority of repairs of the potential causes of failure with the highest RPN in Table 4.3

From the RPN values that have been sorted from highest to lowest, and looking at the combination of SOD that produces Action Priority recommendations, it appears that the priority for improvement is from the aspect of method, human, environment and machine.

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Table 4.2 Failure Mode and Effect Analysis machine GMA H-40

Failure	*Causes*	*Effect*	*S*	*O*	*D*	*RPN*	*AP*
Reduce speed	There is not enough work standardization in the work instructions for operating the GMA machine	Parameter settings that change frequently (depending on operator experience)	7	6	7	294	Yes
Reduce speed	Inadequate training for new operators (often alternating)	Operator error in machine operation settings	5	7	8	280	Yes
Reduce speed	Poor air circulation	Hot environment that causes the operator to lack concentration	4	8	5	160	Yes
Reduce speed	Age of engine usage	The performance of several components has decreased	7	5	6	210	Yes
PLC: The hardware component is damaged (program locked)	Periodic maintenance is not done routinely	Some components do not work	7	5	3	105	Yes
Hydraulic Pump Damage at the balloon accumulator and valve	Valve is not routinely replaced / not checked periodically	The machine cannot do injection	7	5	5	175	Yes

(Source: Data Processing Results, 2019)

Table 4.3 The cause of failure is an Action Priority

No	Cause of Failure	Kategory (RPN)
1	Work instructions that have not been detailed include the parameter settings	Method (294)
2	Inadequate training for new operators who frequently change	Man (280)
3	Air circulation in the production area which still needs improvement	Environment (160)
4	Age of engine usage	Machine (210)
5	PLC that does not have periodic checks	Machine (105)
6	Valve on the hydraulic pump that has not been replaced regularly	Method (175)

(Source: Data Processing Results, 2019)

4.4. Determination of Corrective Action

Based on data processing, analysis and discussion that have been carried out and referring to the research objectives, the proposed improvements can be submitted as follows:

1) Improving Working Method

The step to improve work methods is related to the application of the TPM Office (Maintenance Management System) and Kobetsu Kaizen pillars. Some recommended improvement items are:

- Revised Work Instructions for operation of the GMA H-40 Machine with the addition of more detailed preparation items related to raw materials, PPE and personnel requirements.
- Addition to the pressure parameter setting (min 25 Psi)
- Prepare a Failure Tag to give a visual signal if there is an abnormality in the machine that can be done independently by the operator and record it in the check sheet.

2) Improving Human Factors

The improvement steps for humans are related to the application of the TPM Training & Education pillar.

Some recommended improvements items are:

- Prepare training modules for operators in carrying out Autonomous maintenance;
- Plan training to explain the use of Work Instructions in operating machines;
- Monitoring the skill matrix by the supervisor so that machine operation errors from human factors can be reduced by planning training.

3) Improving Machine

The improvement steps for the Machine in the case of reduce speed losses can be related to the application of the Early Equipment Management TPM Pillar.

Some recommended improvements items are:

- Identifying critical spare parts that must be done with predictive maintenance such as hydraulic valves and injection nozzles;
- Coordinate with the inventory function to ensure the availability of spare parts in the category of critical spare parts;
- Ensuring the preventive maintenance schedule that is arranged by the Equipment section can be carried out consistently and well informed to the Production department.

4) Improving Environment

The steps to improve environmental factors can be related to the application of the TPM Health, Safety & Environment Pillar.

Some recommended improvements items are:

- Add exhaust to the GMA H-40 Engine area so that air circulation can run properly;
- Take prevention by implementing 5S audits regularly.

V. Conclusions

With the completion of the entitled Thesis writing “Analysis of Measurement Equipment Effectiveness Injection Machine GMA with Six Big Losses and FMEA in Manufacture” the following conclusions can be drawn:

Achievement of OEE values from GMA machines in the period April - October 2019 has not reached the average target. Achievement of the actual OEE is only 34.42% with an average

Availability rate of 94.4%, an average Performance rate of 37% and an average Quality rate of 98.62%. The lowest value of the three OEE factors is the Performance rate factor.

From the Pareto Six Big Losses diagram, it was found that the dominant factor that contributed the biggest losses was Reduce Speed Losses with a percentage of 88.8% of the total losses. As for the main causes of these losses if sorted from the largest is the method, human, machine and work environment factors.

The proposed improvement of the engine maintenance system of the GMA H-40 refers to the main cause of the losses by implementing several TPM pillars, namely improving work procedures, then scheduled training for operators, then identifying critical spare parts, then performing air circulation improvements to improve environmental quality work, as well as conducting periodic 5S audits.

VI. Suggestion

From the results of this study, the recommendations from authors for companies and manufacturers are:

Improve work methods by re-standardizing the work instructions for the operation of the machine by adding more detail to the raw material preparation items, PPE that must be used, personnel requirements that can operate the machine and setting pressure parameters, namely min 25 psi.

Then apply the Autonomous maintenance pillar with the aim that the operator is more aware of the abnormality conditions that affect the speed of the machine, by doing a self-check together with the start-up process using the Failure Tag form.

It also needs to improve the ability of operators by preparing training modules for operators in carrying out autonomous maintenance, ensure that each new operator has received an explanation from the Work Instructions for operating the machine, monitoring the skill matrix by the supervisor so that machine operation errors from the human factor can be reduced by planning additional training if there are still gaps in ability.

Then, the company must also ensure the reliability of the machine even though it has reached a long service life by identifying critical spare parts that must be carried out periodically checking and managing inventory of spare parts, ensuring the preventive maintenance schedule arranged by the equipment can be carried out consistently and well informed to the part Production.

The final recommendation is for the company to improve environmental factors by adding exhaust to the GMA H-40 engine area so that air circulation can flow properly and carry out 5S audits that are consistent to maintain a clean and motivating work environment.

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