A Recommendation of breakdown maintenance on vehicle engine camshaft line using Reliability Centered Maintenance and FMEA methods

(*Usulan pemeliharaan kerusakan pada saluran camshaft engine kendaraan menggunakan metode Reliability Centered Maintenance dan FMEA*)

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Abstract. *A vehicle engine manufacturing company aims to implement Total Productive Maintenance (TPM) to increase engine productivity. This research's background is the high rate of machine breakdown on the Camshaft Line from January to May 2019. The breakdown will be reduced by optimizing preventive maintenance with the Reliability Centered Maintenance (RCM) method using Failure Mode and Effect Analysis (FMEA) and Logic Tree Analysis (LTA). Based on the data collected for each machine's breakdown time, it was found that the highest failure occurred in the IGR-0040 machine, which was 22.23 hours. The availability is 72.88% and the reliability is 55%. Reliability does not meet the production machine standards. FMEA and LTA methods were used to identify machine failures and found six engine components with a high failure rate. The researcher recommends improving the preventive maintenance scheduling time interval of 10 hours with the results being able to increase the Reliability by up to 61%.*

Keywords: TPM, camshaft engine, Reliability Centered Maintenance, FMEA, Logic Tree Analysis.

Abstract. *Sebuah perusahaan manufaktur mesin mobil bertujuan menerapkan Total Productive Maintenance (TPM) untuk meningkatkan produktivitas mesin. Hal ini dilatarbelakangi oleh tingginya tingkat kegagalan mesin pada lini Camshaft yang terjadi selama bulan Januari hingga Mei 2019. Jumlah kegagalan mesin pada lini Camshaft akan dikurangi dengan mengoptimalkan perawatan preventif menggunakan metode Reliability Centered Maintenance (RCM), Failure Mode and Effect Analysis (FMEA), dan Logic Tree Analysis (LTA). Berdasarkan data historis waktu kerusakan setiap mesin, ditemukan bahwa kegagalan tertinggi terjadi pada mesin IGR-0040 yaitu sebesar 22,23 jam. Nilai availability sebesar 72,88% dan reliability sebesar 55%. Nilai reliability index tersebut tidak memenuhi standar mesin produksi. Metode FMEA dan LTA digunakan untuk mengindentifikasi kegagalan mesin dan menemukan bahwa terdapat 6 komponen mesin dengan tingkat kegagalan yang tinggi. Peneliti merekomendasikan perbaikan interval waktu penjadwalan perawatan preventif yaitu 10 jam dengan hasil dapat meningkatkan Reliability hingga 61%.*

Keywords: TPM, Reliability Centered Maintenance, FMEA, Logic Tree Analysis, camshaft engine.

1. Introduction

TPM aims to increase the maintenance efficiency and effectiveness of a company. In other words, the goal of TPM is to maintain a machine by optimizing the equipment's effectiveness, reducing sudden damage, and self-maintenance by the operator to increase machine productivity to achieve cost savings (Prabowo *et al.*, 2020). A manufacturing company that produces vehicle engines aims to increase efficiency and improve machine maintenance activities using Total Productive Maintenance (TPM). The camshaft line on this manufacturing company has three machines, namely turning machines, milling machines, and grinding machines. Figure 1 shows the camshaft line's layout, consisting of turning, milling, and grinding machines. The camshaft line begins with the cylinders' surface by a turning machine in the production process, then continues with material refining by a milling machine. Finally, the finishing process is carried out with a grinding machine. After all the processes complete and pass the quality control, the camshaft can be brought to the assembly line. A fault occurs when the cover part on the turning machine is out of position. That fault causes the iron particles leftover from the process to scatter all over the line and interfere with the production process. Ideally, this incident should not occur if Total Productive Maintenance is carried out correctly in preventive maintenance scheduling. The researcher carried out further investigations into the camshaft line.

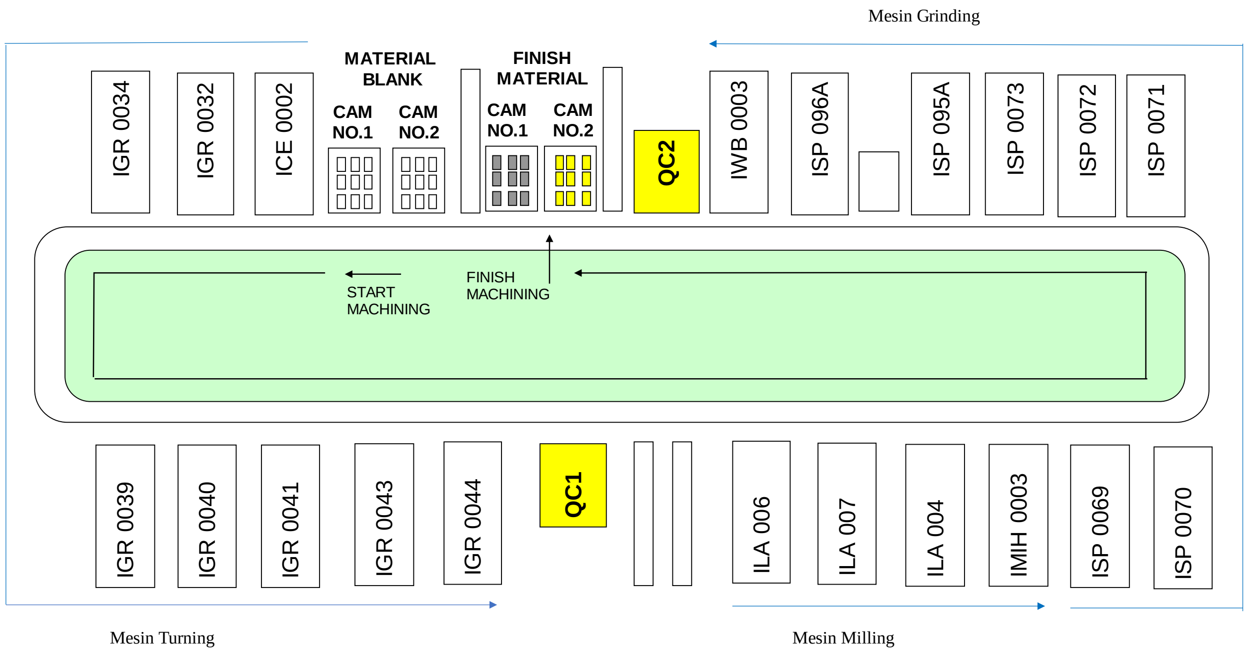

Figure 1 Camshaft Line Process Layout.

Figure 2 shows the actual breakdown of the Camshaft Line during January-August 2019. However, according to data from the vehicle engine company's maintenance department, the engine experienced a significant breakdown in the camshaft line that occurred from January to May 2019, which resulted in the disruption of the production process.

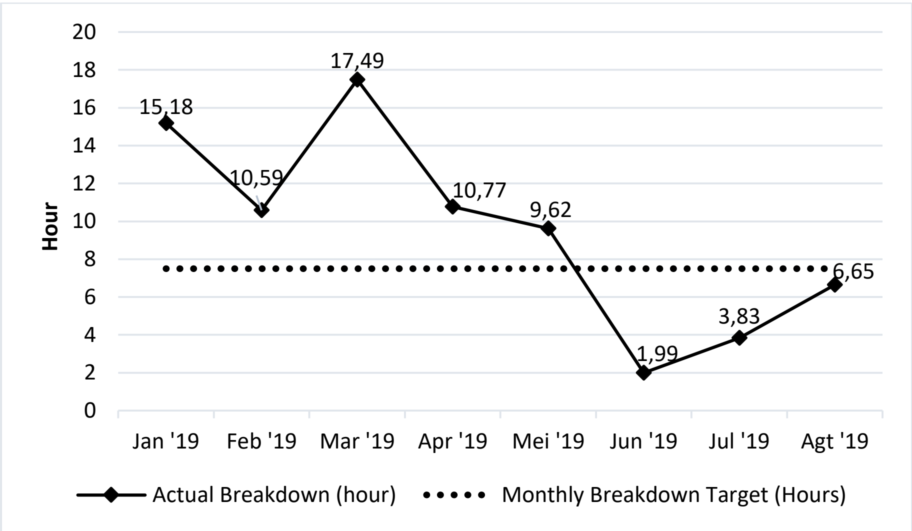

Figure 2 Actual Breakdown of Camshaft Line during January - August 2019.

In this study, the breakdown will be reduced by optimizing preventive maintenance with the Reliability Centered Maintenance (RCM) method using Failure Mode and Effect Analysis (FMEA) dan Logic Tree Analysis (LTA). This method is expected to help implement Total Productive Maintenance (TPM) to increase machine productivity at this manufacturing company.

2. Literature Review

Maintenance is a job carried out sequentially to maintain or repair existing facilities to follow standards (according to operational and quality standards) (Sabouhi *et al.*, 2017). Maintenance is needed to maintain and return the machine to the optimal condition to perform optimally (Susetyo & Nurhardianto, 2019). The method for determining the maintenance department's activities aims to ensure system reliability is known as RCM (Reliability Centered Maintenance). This research utilizes the RCM method considering its advantages in identifying malfunctions and preventing them from recurring (Lee *et al.*, 2013).

RCM is a process that is carried out to determine the planning to ensure that all physical assets are in the form of equipment or machines so that users can operate these assets normally and effectively (Sunaryo *et al.*, 2018). The output obtained from the RCM is knowing the critical components with equipment maintenance time intervals according to their respective function tasks (Afiva *et al.*, 2019). There are five main steps in implementing RCM (Palit and Sutanto, 2012). The first is determining the system's focus and boundaries. The second is to identify functional failures and calculate their index. The third is to evaluate failure modes using FMEA. Then it analyzes the priority of failure using LTA. Furthermore, the last is to measure the preventive maintenance time interval. Moreover, the researchers will explain the literature reference about FMEA, LTA, and preventive maintenance time interval.

System Focus and Boundaries

The chosen system is the most expensive maintenance costs system and has the most influential function in systems with high corrective maintenance frequency. The researcher can use Pareto Diagram to determine system focus and boundaries (Taufik & Septyani, 2016).

Functional Failures

Functional failure is the inability of equipment to carry out activities according to its function. There are some indicators of functional failures, which are:

a. Reliability. It is the time of possibility (probability) that the equipment can operate well under normal conditions (Suwanda & Supriyadi, 2019). Reliability is measured by Mean Time Between Failure (MTBF), which is the average time a machine can be operated before failure occurs (Maulana *et al.*, 2019).

$$MTBF = \frac{Total\ Operation\ Time}{frequency\ Breakdown} \times\ total\ item$$

b. Maintainability, which is measured by Mean Time to Repair (MTTR). It is an indicator of the machine maintenance operator's ability (skill) to handle or overcome any damage problems (Farobi & Muslimin, 2019).

$$MTTR = \frac{Breakdown\ Time}{frequency\ Breakdown}$$

c. Mean Time to Failure (MTTF) the average time to failure (Farobi & Muslimin, 2019).

$$MTTF = Total\ Operation\ Time - Breakdown\ Time$$

d. Availability (A) is the amount of time the equipment or machine is available to do a job with a specified time to do a job (Prasmoro, 2020).

$$A = \frac{MTTF}{MTBF + MTTR} \times 100\%$$

Failure Mode and Effect Analysis (FMEA)

Failure Mode Effect Analysis (FMEA) evaluates failures that occur in a system, design, process, or service (Ahmadi & Hidayah, 2017). FMEA also aims to analyze failure modes in a system so that it can be used to determine or decide on actions to prevent and fix them (Denur *et al.*, 2017). FMEA has several procedures. They identify the components and their function, determine each component's failure's mode and effect, and measure each component's value of severity, occurrence, and detectability. The RPN (Risk Priority Number) comes from multiplying the severity, occurrence, and detectability (Nurato *et al.*, 2015).

$$Risk\ Priority\ Number\ (\mathrm{RPN}) = Severity\ (\mathrm{S}) \times Occurrence\ (\mathrm{O}) \times Detection\ (\mathrm{D})$$

Logic Tree Analysis (LTA)

Logic Tree Analysis (LTA) is a qualitative process that prioritizes each mode of damage and performs an analysis of the failure function to determine which damage must take precedence (Susanto, 2017).

Preventive Maintenance Time Intervals

The decision to replace system components based on the minimum breakdown is critical because maintenance management's main principle is to suppress the period of damage to the minimum (Ahmadi & Hidayah, 2017). Preventive maintenance aims to determine the optimal maintenance time interval so that the machine reliability can be maintained and the machine can be appropriately operated before the upcoming maintenance schedule.

3. Research Method

This research applies the steps of the RCM methods. These steps include literature study and data collection, defining problem focus, determining the functions and calculating functional failures, identifying the failure mode and effect analysis (FMEA) and logic tree analysis (LTA), and measuring preventive maintenance time intervals. The researchers observed the camshaft line's current process and interviewed some operators regarding the machines' current performance. Besides, we also collect secondary data such as the number of machine breakdowns and the time to repair it. After obtaining all the required data, the researchers process the data following the steps in Figure 3.

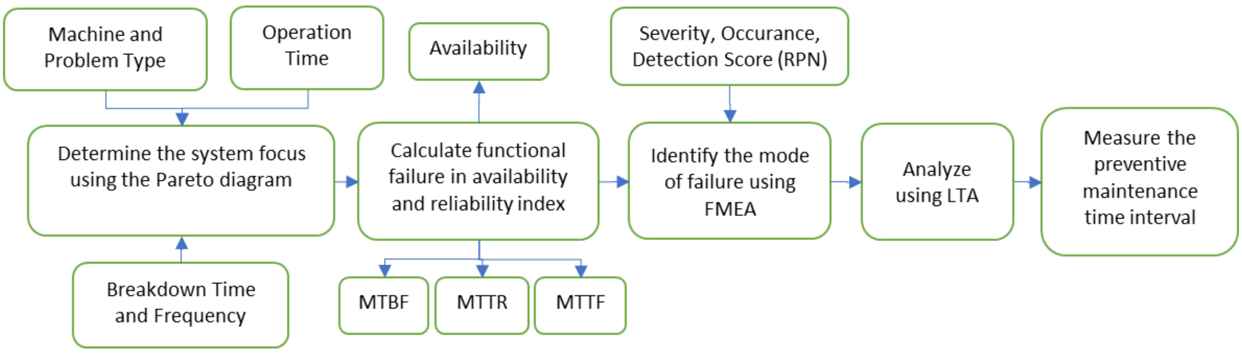

Figure 3 Research Steps Utilizing RCM Method.

4. Result and Discussion

System Focus and Boundaries

This research aims to determine the camshaft line's highest failure, as shown in the Pareto Diagram (Figure 4).

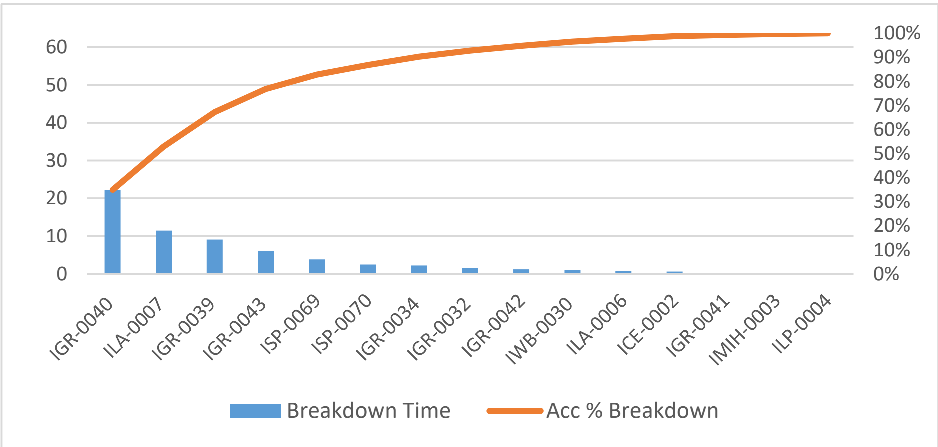

Figure 4 Pareto Diagram of Breakdown Camshaft Line.

From the Pareto diagram results, the total breakdown maintenance time on the camshaft line is 63.65 hours, and the highest breakdown maintenance time is in the IGR-0040 machine with a breakdown time of 22.23 hours. An IGR-0040 machine is a turning machine. Figure 5 visualize the components of the turning machine. Some factors that affect high breakdown time were machine availability and Reliability, poor machine reliability conditions, and inappropriate preventive maintenance interval time.

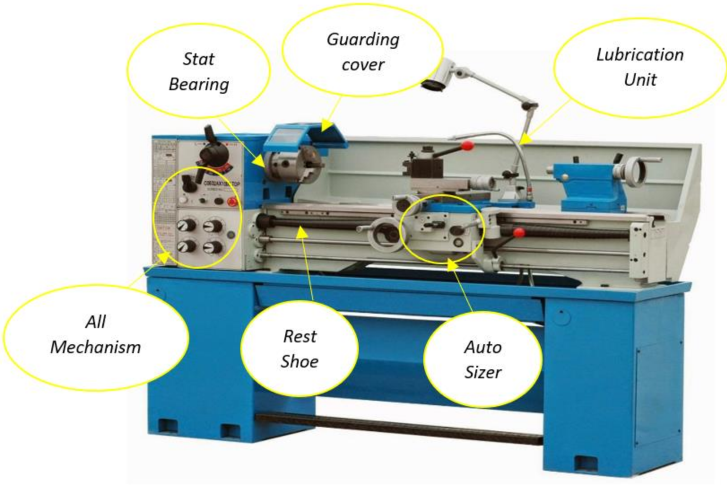

Figure 5 Turning Machine Components.
(Source: Adi, 2010)

Function Determination and Failure

The researchers calculate function failure as follow:

a. Mean Time Between Failure (MTBF)

$$MTBF = \frac{2160}{14} \times 19 = 2931{,}4 \text{ hour}$$

b. Mean Time to Repair (MTTR)

$$MTTR = \frac{22{,}23}{14} = 1{,}86 \text{ hour}$$

c. Mean Time to Failure (MTTF)

$$MTTF = 2160 - 22{,}23 = 2137{,}77\ jam$$

d. Availability

$$A = \frac{2137{,}77}{2931{,}4+1{,}86} \times 100\% = 72{,}88\%$$

The IGR-0040 machine's Availability was 73%, which means it did not meet the JIPM (The Japan Institute of Plant Maintenance) standard (89.6%). The preventive maintenance time interval is calculated to grasp the ideal preventive maintenance time. This study utilized the Minitab Software to calculate the distribution, starting by calculating Reliability.

After the breakdown time data is obtained, the data is carried out by normal distributions shown in Table 1.

Table 1 ***Goodness of Fit***

Distribution	*Anderson Darling*	*Correlation Coefficient*
Weibull	1,131	0,977
Lognormal	1,504	0,929
Exponential	1,503	*
Normal	1,268	0,961

Weibull distribution was chosen because it has the highest Correlation Coefficient value, namely 0.977. After obtaining the Goodness-of-fit distribution, distribution processing is carried out using the Weibull distribution to determine the Shape (β) and Scale (ϴ) values to be used as a source for determining Reliability using Minitab software, as shown in Table 2.

Table 2 Weibull distribution results using Minitab Software

No	Description	Score
1	Shape	0,6963
2	Scale	13,9569
3	Mean	11,7551
4	StDev	10,5339
5	Median	10,6982
6	IQR	12,6187
7	Failure	14
8	Censor	0
9	AD*	1,147

It is known that the camshaft line machine operates with preventive maintenance in a period of t = 12 hours, so the camshaft line machine reliability can be obtained as follows:

$$R\ (t) = exp - (\ t/\Theta)^{\beta}$$

$$R\ (t) = exp - (\ 12/13{,}9569)^{\ 0{,}6963}$$

$$R\ (t) = 0{,}549541 \text{ or } 55\%$$

The result shows that the preventive maintenance of the IGR-0040 machine was carried out in 12 hours, the Availability is 72.88%, and Reliability is 55%.

Failure Mode and Effect Analysis (FMEA)

FMEA is used to identify failures that occur in the IGR-0040 machine. The researchers conduct interviews to get severity, occurrence, and detection, as in Table 3.

Table 3 Failure Mode and Effect Analysis

Date	*Item*	*Failure Mode*	*Failure Effect*	*Severity*	*Occurrence*	*Detection*	*RPN*
09/01/2019	Rest Shoe	Process results in the journal five oval	The rest shoe pressure is not correct	6	2	5	60
07/01/2019	Auto Sizer	Autocycle condition fault	Setting auto sizer	4	2	4	32
03/01/2019	Guarding Cover	Part holder does not want the home position	Detection work unloading is not on	4	2	3	24
20/02/2019	Rest Shoe	The results of the grinding process of the journal five scratch	The rest shoe is dirty, and the pressure is not correct	6	2	5	60
26/02/2019	All Mechanism	Chocotei alarm b953	Auto-sizer signal is error	4	2	4	32
15/02/2019	All Mechanism	Shutter open/close no end	Broken shutter cylinder bracket	4	2	3	24
26/02/2019	Auto Sizer	Alarm b935 auto sizer already on	Auto-sizer accuracy is not optimal	4	2	3	24
18/02/2019	Rest Shoe	The results of the journal process one taper	Rest shoe pressure is unstable.	6	2	5	60
26/03/2019	Rest Shoe	Journal diameter 1 is unexpectedly large	Broken proximity	4	2	4	32
08/03/2019	Lubrication Unit	Auto sizer fault (alarm 953)	Lubrication oil mixed with coolant	4	2	4	32
08/05/2019	All Mechanism	TRK detection works not on	The proximity switch does not go up enough	3	2	3	18
08/05/2019	Stat Bearing	Part consistent fault (work fault)	Lack of lubrication bearing	6	2	3	36
12/05/2019	*Rest Shoe*	The result of diameter j # 5 is not stable	*Auto-sizer reading error*	6	2	5	60

Date	*Item*	*Failure Mode*	*Failure Effect*	*Severity*	*Occurrence*	*Detection*	*RPN*
23/05/2019	*Rest Shoe*	The results of the grinding process of the journal five scratch	The rest shoe pressure is not correct	6	2	5	60

Logic Tree Analysis (LTA)

The next step to diagnose the IGR-0040 machine was the analysis. LTA is used to prioritize and analyze the failure mode. Logic Tree Analysis (LTA) categorized the action which can cause failure in all or part of the system, shown in Table 4.

Table 4 LTA results

Date	*Item*	*Failure*	*Action*	*RPN*	*Category*
09/01/2019	*Rest Shoe*	Process results in the journal five oval	*Rest shoe pressure setting*	60	B
07/01/2019	*Auto Sizer*	*Autocycle condition fault*	Setting auto sizer	32	C
03/01/2019	*Guarding Cover*	Part holder does not want the home position	*Setting guide rail work(rear)*	24	B
20/02/2019	*Rest Shoe*	The results of the grinding process of the journal five scratch	Cleaning and setting rest shoe	60	B
26/02/2019	*All Mechanism*	*Chocotei* alarm b953	*Setting b axis*	32	B
15/02/2019	*All Mechanism*	*Shutter open/close* no *end*	*Repair bracket*, las to kaizen	24	B
26/02/2019	*Auto Sizer*	*Alarm b935 auto sizer already on*	Setting zero auto sizer	24	C
18/02/2019	*Rest Shoe*	The results of the journal process one taper	*Rest shoe pressure setting*	60	B
26/03/2019	*Rest Shoe*	Journal diameter 1 is unexpectedly large	*Rest shoe pressure setting*	32	B
08/03/2019	*Lubrication Unit*	*Auto sizer fault* (alarm 953)	*Cleaning lubrication unit*	32	C
08/05/2019	*All Mechanism*	TRK detection works not on	*Setting a proximity switch*	18	B
08/05/2019	*Stat Bearing*	*Part consistent fault (work fault)*	Bearing lubrication	36	C
23/05/2019	*Rest Shoe*	The result of diameter j # 5 is not stable	*Rest shoe pressure setting*	60	B
23/05/2019	*Rest Shoe*	The results of the grinding process of the journal five scratch	*Cleaning* and *setting rest shoe*	60	B

The Recommendation for Preventive Maintenance Time Interval

In this stage, a recommendation is made to improve the preventive maintenance time interval, then processing the parameter distribution to determine the shape (β) and threshold (γ) values to be used as a source for determining the preventive maintenance time using Minitab software. The results can be seen in Table 5.

Table 5 ***Distribution Parameter***

Distribution	*Location*	*Shape*	*Scale*	*Threshold*
Weibull	IGR-0040 machine	0,6963	13,9569	9,63399

From the Shape (β) and threshold (γ) data obtained, the proposed preventive maintenance time can be calculated as follows:

$$t_{pm} = \theta(-in\ 0{,}85)^{\frac{1}{\beta}} + \gamma = 1{,}69630\ (-in 0{,}85)\ \frac{1}{1{,}26569} + 9{,}63399 = 9{,}8518 \text{ hours or } 10 \text{ hours}$$

The reliability calculation base on 10 hours of preventive maintenance time is:

$R\ (t) = exp - (\ 9{,}85/13{,}9569)^{0{,}6963}$
$R\ (t) = exp - (0{,}705744112)^{0{,}6963}$
$R\ (t)$ = 0,611763 atau 61%

By the reliability of 61%, the estimated availability is become 77.5%.

A proposed preventive maintenance improvement is obtained from all the discussions carried out, as shown in Table 6.

Table 6 Preventive Maintenance Reccomendation

No	Item Machine	Action	RPN	LTA	Repair Period (Hours)
1	*Rest Shoe*	*Cleaning and setting rest shoe pressure*	300	B	10
2	*All Mechanism*	*Setting b axis and proximity switch*	74	B	10
3	*Auto Sizer*	*Setting auto sizer*	56	C	10
4	*Stat Bearing*	*Bearing lubrication*	36	C	10
5	*Lubrication Unit*	*Cleaning oil lubrication*	32	C	10
6	*Guarding Cover*	*Setting guide rail work*	24	C	10

The preventive maintenance time interval is 10 hours. The improvement recommendation includes cleaning and setting the pressure of rest shoe, setting axis and proximity switch, setting auto sizer, bearing lubrication, cleaning oil lubrication, and setting the guide rail work.

5. Conclusion

The total breakdown time on the camshaft line machine is 63.65 hours, with the highest breakdown of is IGR-0040 machine (22.23 hours). Some factors that affect high breakdown time were poor machine reliability conditions and inappropriate preventive maintenance interval time. The camshaft line machine operates with 12 hours of a preventive maintenance time interval. The Availability is 72.88%, and the Reliability is 55%, which means it did not meet standard (89.6%). The use of FMEA and LTA helped to identify machine failures. There were six engine components with a high failure rate. The rest show all mechanisms, auto sizer, stat bearing, lubrication unit, and guarding cover. The researcher recommends improving the preventive maintenance scheduling time interval of 10 hours with cleaning and re-setting rest shoe pressure, axis, auto sizer, guide rail work, and lubrication. The results show that this recommendation is being able to increase Reliability by up to 61%.

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