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RELIABILITY ANALYSIS AND MAINTENANCE MANAGEMENT EVALUATION OF FLASH BUTT WELDING MACHINE WITH RCM II

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ABSTRACT

PT INKOASKU is a leading company dedicated to steel wheel rim manufacture for passenger car and pick up which has more than 50 production machine as the company's physical assets. One of those production machines is Flash Butt Welding that serves to weld both sides of the material with 3 critical steps called Preheat-Flashing-Upsetting. FBW is maintained by performing the scheduled maintenance activities which are expected to eliminate potential failures that may occur. In order to improve maintenance performances, the Reliability Centered Maintenance is selected as the method to determine the appropriate maintenance actions for each component of the machine. The analysis has 3 sub-methods which are Functional Block Diagram to analyze machining flow process; FMEA (Failure Mode & Effect Analysis), and LTA to analyze functional failure consequences. The analysis has categorized the best preventive maintenance actions such as 12 components are categorized as Scheduled On-Condition Task, 3 components are categorized as Failure Finding Task, etc. Analyzing the reliability by calculating the value of MTTF and MTTR for each component is done to complete this study. The final result provides 23 proposed actions along with the maintenance schedule as an improvement of maintenance performances.
Keywords : RCM, FBD, FMEA, Reliability

1. INTRODUCTION

Reliability is the ability or probability of a system (machine, component, or product) will perform its specified function under the specified condition throughout its specified life expectancy (Stephens, 2004). In other words, reliability is the ability of a machine that have been exceeded its expected life period, should be able to perform its function at its expected level of capacity. One of the supporting factors of reliability is the ability of the company to perform maintenance and repair machinery at good level and also the ability to fulfill these kinds of spare parts needed. As long as the production machines are in their optimal conditions, production is expected to be on time without any obstacles such as the production line stopped because of engine failure.

PT Inkoasku is a leading company dedicated to steel wheel rim manufacture for passenger car and pick up or minibus which has many types, sizes, and two different colors with different coating process. The company's production capacity is 2.6 million units per year with 32 variations of disc type and 29 variations of rim type. The main material of steel wheel rims are aluminum steel special in plate shaped which allows to do recognition in the form of cutting, stamping, coiling, flaring, forming, and force-fitting. This continuous machining process makes company needs to conduct an improvement activities that focus on optimal maintenance machining techniques and structured to improve the performance of production machines.

In this study, improvement activities will be pursed to the mapping problem of machining into the machine functions, the machine failures, the consequences of failures, until the appropriate remedial actions along with the calculation of time while the failures occur and record it into a worksheet with RCM II approach. RCM or Reliability Centered Maintenance is used to identify applicable and effective Preventive Maintenance task (Eisinger and Rakowsky, 2001). It used a structured, logical process in optimizing the maintenance requirements of physical resource in order to realize its inherent reliability. In other words, RCM is a process to determine the maintenance

requirement of any equipment in its operating context by identifying the functions of the equipment, the causes of failures and the effects of the failures. This RCM method will be applied for Flash Butt Welding (FBW) machine.

FBW machine is one of the production machines on the rim line production which serves to combine both sides of the plate circumference with welding process. FBW machine is selected as the research object with the consideration of the failure effects and downtime levels are quite high. The average failure rates throughout 2015 is >10 times per month with the average downtime is +40 minutes. The longest downtime throughout 2015 occurred in May, which is 1518 minutes or 25.3 hours. This incident occurred due to the unpredictable failure which caused the company suffered big losses due to the limited stock because of the decrease production number and delays. Based on this incident, RCM II is necessary needed in order to be able to analyze the preventive action and machining reparation according to the failure modes and minimize the failure consequences.

2. RESEARCH METHOD

2.1. Data Collecting

In this study, data collected by three methods, which are 1) Observation Method; 2) Interview Method; and 3) Documentation Method. Observation method is done by direct observation of the real situation in the company regarding the maintenance system. Interview method is done by direct interview with employees about the company's policy of handling failures and maintenance management. Documentation method is done by collecting data such as operator's notes, maintenance department's archives, FBW machine's manual book, and any other documents related. Figure 1 shows research method used in this case study.

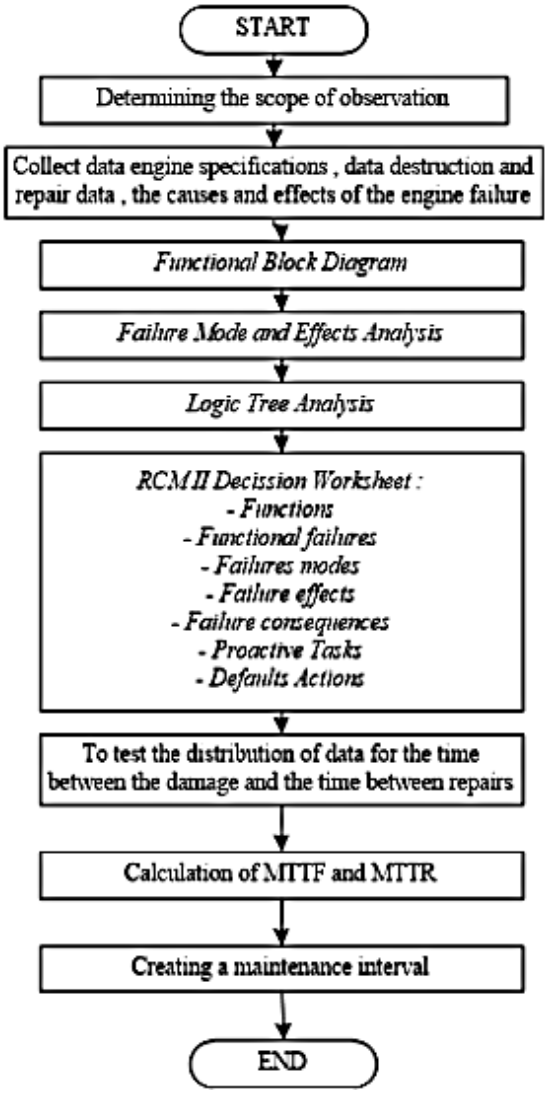

Figure 1. Research Method

2.2. Data Processing

Data processing is performed to obtain FBD, FMEA, LTA, RCM Decision Worksheet, the distribution type, value of MTTF and MTTR, as well as maintenance interval.

1) Functional Block Diagram (FBD)
FBD drawing is done based on the operating system Flash Butt Welding machine with automatic system which includes the circuit of operating system inside the machine up to the output of the process (Putra,2011).

2) FMEA Worksheet
After understanding the process flow of the machine through the FBD, followed by making FMEA Worksheet that identifies functions, functional failures, failure modes, and failure effects. Then, calculate the value

of the RPN (Risk Priority Number) based on three main aspects, which are *Severity, Occurrence,* and *Detection* (Villacourt,1992).

3) Logic Tree Analysis (LTA)
LTA performed to determine the category of the failure consequences caused by a failure modes. This analysis will provide the form of four consequence categories named A,B,C,D which are obtained based on three basic questions of LTA, such as Evident, Safety and Outage. The result of the LTA will become one of variable input for RCM Decision Worksheet along with the result of FMEA as well.

4) RCM Decision Worksheet
After the FMEA Worksheet and LTA analysis is completed, all of the results are summarized in a worksheet named RCM Decision Worksheet. This worksheet will help the company to visualize the failure consequences based on the personal standpoint, organization point, and environmental standpoint. Additionally, RCM Decision Worksheet also provides another separate sheet in the form of maintenance actions categories based on Preventive Task and Default Task analysis.

5) Distribution Test
The test is conducted on machining historical data which has been collected in order to see the trend of the distribution of data patterns. Distribution of breakdown machine consist of four distribution, namely Normal; Lognormal; Exponential; and Weibull (Walpole, 1982). The test can be done manually or with a software program named Minitab-16.

6) Calculation of MTTF and MTTR
The calculation of MTTF (Mean Time To Failure) is conducted based on the interval between each failures in FBW machine, while MTTR (Mean Time To Repair) calculation is conducted based on the length of the time required to repair each failures. Both of these calculations done manually by a formula adjusted to the distribution of the data.

7) Maintenance Interval
This calculation afterwards can be done as an application of RCM method by making a schedule for maintenance operation throughout the coming years along with the preventive task's description which suited the company very well.

3. RESULT AND DISCUSSION

3.1. *Functional Block Diagram* (FBD)

The flow of FBW machining process with automatic system can be seen in Figure 2 below.

3.2. *Failure Mode and Effect Analysis* (FMEA)

FMEA is a method used to identify the failure modes that might cause any malfunction and to ascertain the effect of the failure associated with the failure modes itself (Moubray, 1991). To identify the cause of the highest failure at every failure that occurs in the subsystem "Flashing & Upsetting Devices" in FBW machine, therefore the calculation of the RPN by multiplying the assessment of Severity, Occurrence and Detection of each cause of failure. RPN calculation formula is as follows.

$$RPN = S \times O \times D$$

FMEA calculation showed five highest result of RPN lies in the *Limit Switch, Contact Relay, Solenoid Valve, Flexible Hose,* and *Air Regulator.* The examples of the FMEA results are shown in Table 1.

3.3. *Logic Tree Analysis* (LTA)

LTA classifies the consequences of failure into four categories, namely a) A Category, if the failure modes have consequences for the safety of the personnel and the environment *(Safety & Environment Category);* b) B Category, if the failure modes have consequences for the operations of the production both in terms of quality and quantity of products which can cause significant economic losses *(Operational Category);* c) C Category, if the failure modes does not affect the level of

safety and operational activities and only cause economic loss which is relatively small for repairs *(Non-Operational Category);* and d) D Category, if the failure modes belong to the hidden failures, which is then broken down into several categories such as D/A, D/B, and D/C (Moubray, 1991). Moubray (1991) also explain these four categories are the answer of the three LTA's basic questions, which are *a) Evident* (Does the operator under normal circumstances know there has been a failure or abnormality on the machine?); *b) Safety* Does the failure modes threaten the safety level?); dan *c) Outage* (Does the failure modes make a whole or some part of the machine stops?). The results of LTA worksheet then used as a basis to create an RCM worksheet.

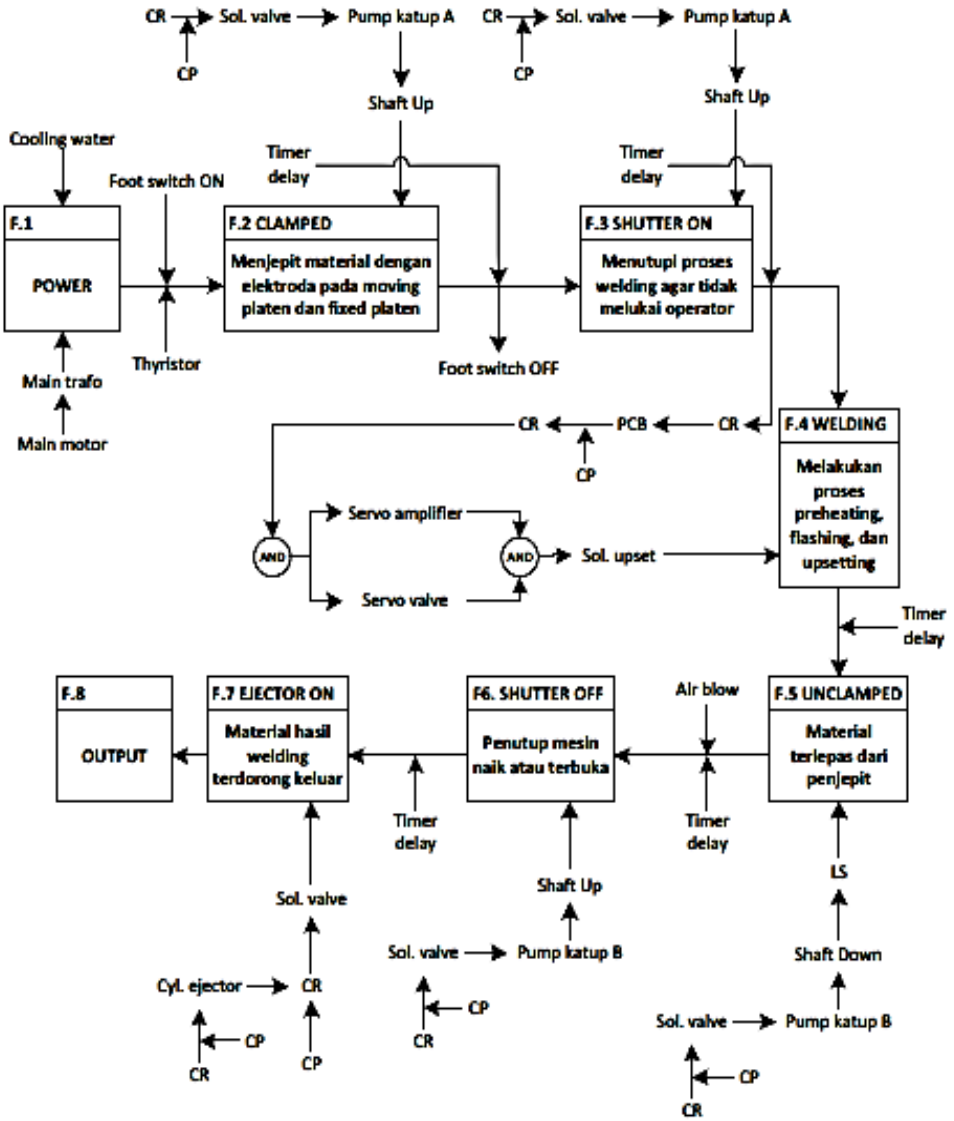

Figure 2. *Functional Block Diagram* FBW

3.4. *Reliability Centered Maintenance* (RCM)

RCM worksheet arranged based on the results of FMEA and LTA. Then the determination of Preventive Task and Default Task on worksheet adjusted based on the categories of task in RCM Decision Diagram. At subsystem "Flashing & Upsetting Devices" in FBW Machine, the functional failure is not able to perform preheating, flashing and upsetting with its first failure mode is a limit switch may breakdown due to an error setting. This failure mode is hidden so that preventive action or preventive task can't be done

because included in the category of hidden. The results of the analysis can be made as an RCM worksheet which results the proposed task along with the initial maintenance interval and the PIC or person-in-charge of the maintenance activities. The proposed corrective action for failure mode limit switch doesn't work due to incorrect setting is "No Maintenance Scheduled" because this failure mode is concealed of hidden failure. Because of this failure is hidden, the PIC is the maintenance division. RCM worksheet can be seen in Table 2 below.

Table 1. FMEA Worksheet

RCM II INFORMATION WORKSHEET (FMEA)		SYSTEM	FLASH BUTT WELDING	Facilitator:		Date:		Sheet No.
		SUB-SYSTEM	Flashing & Upsetting Devices - Hydraulic System	Auditor:		Date:		of
NO.	FUNCTION	FUNCTIONAL FAILURE *(Loss of function)*	FAILURE MODE *(Cause of failure)*	SEV	OCC	DET	RPN	RANK
1	Conducting the process of grafting material with arc welding methods .	Unable to perform preheating, flashing and upsetting well	Limit switches may malfunction due to incorrect setting.	7	6	6	252	2
			Limit switches may malfunction	8	7	6	336	1
			Roller wear out	6	4	5	120	9
			Handle block broken or loosened so regardless.	7	5	5	175	6
			Cooling water does not flow through the cooling pipe around the point electrode	7	6	5	210	3
			Upset Solenoid not functioning properly.	7	6	6	252	2
			The timer is not running well because sokcet timer slack or because of the influence lifespan	7	4	5	140	8
			Servo amplifier is not synchronized with the servo valve.	8	6	7	336	1
		The machine does not perform the welding process .	Selector Weld ON -OFF switch is not working	7	3	4	84	12
			Push button switches on the panel board is not functioning	7	3	4	84	12
			Welding program control on the PCB problem	7	5	5	175	6
			Contact relay is not functioning due to coil or wire coils inside overheat , burn, melt , or disconnected	7	7	4	196	4

Table 2. RCM Worksheet

RCM II DECISION WORKSHEET			SYSTEM	FLASH BUTT WELDING			Facilitator:			Date:	Sheet No.
			SUB-SYSTEM	Flashing & Upsetting Devices			Auditor:			Date:	of
FMEA			LTA				PREV. TASK			DEF. TASK			PROPOSED TASK	INITIAL INTERVAL	PIC
F	FF	FM	H	S	E	O	H1 S1 O1 N1	H2 S2 O2 N2	H3 S3 O3 N3	H4	H5	S4			
1	A	1	Y	N	N	Y	N	N	N				There are no scheduled maintenance or repair activities	-	MTC
1	A	2	Y	Y	Y	Y	N	N	N				There are no scheduled maintenance or repair activities	-	MTC
1	A	3	Y	N	N	Y	Y						Perform scheduled lubrication system	8 jam	MTC
1	A	4	Y	Y	N	Y	N	N	Y				Replace handle block	3 tahun	MTC
1	A	5	Y	N	N	Y	Y						Checking the flow of cooling water and indicate leaks in pipelines or flexible hose	1 hari	Operator
1	A	6	Y	N	N	Y	Y						Perform lubrication system and purge solenoid scheduled	8 jam	MTC
1	A	7	Y	Y	Y	N	N	N	Y				Change timer	1 tahun	MTC
1	A	8	Y	Y	Y	Y	N	Y					Note synchronizing servo valve servo amplifier with each conducting overhaul	6 bulan	MTC
1	B	1	Y	N	N	Y	N	N	N				There are no scheduled maintenance or repair activities	-	MTC

3.5. Reliability Analysis

Reliability calculation includes distribution testing, calculation of distribution parameters and the calculation of MTTF and MTTR. FBW's interval data between each failure and each repair which have been previously collected will be tested to determine the type of distribution based on the highest value of Index of Fit (IOF). As for *limit switch,* the

distribution type of interval breakdown is Weibull Distribution with IOF score around 0.9954 with the value of parameters are β = 2.973, α = -17.353, θ = 342.703 while the distribution type of interval repair for *limit switch* is Lognormal Distribution with IOF score around 0.979 and the value of parameters are μ = 3.4829 and σ = 0.168.
After getting each type of distribution, then calculate the average between failure time or Mean Time To Failure (MTTR) and the average between repair time or Mean Time To Repair (MTTR). MTTF and MTTR formula will be adjusted by each type of distribution. The calculations which have been done on limit switch provided value of MTTF around 306.16 hours and MTTR's value around 33.01 minutes. MTTF value indicates that there is a potential breakdown for limit switche after 306.16 hours of usage. Then the value of MTTR showed that the average time required to repair the breakdown of limit switch is 33.01 minutes. The summary of distribution types, parameter values, and the value of MTTF and MTTR for each component are presented in Table 3 below.

Table 3. Value of MTTF and MTTR

Komponen	Data	Distribusi	β	α	θ	μ	σ	Index of Fit	MTTF (jam)	MTTR (menit)
Limit Switch	Damage	Weibull	2.973	-17.353	342.703	-	-	0.9954	306.16	-
	Repair	Lognormal	-	-	-	3.4829	0.168	0.979	-	33.01
Contact Relay	Damage	Normal	0.0012	-4.9418	-	398.70	80.68	0.9677	398.70	-
	Repair	Lognormal	-	-	-	3.0066	0.2045	0.9784	-	20.64
Solenoid Valve	Damage	Normal	0.010	-5.9154	-	558.91	94.485	0.9724	558.91	-
	Repair	Lognormal	-	-	-	3.5371	0.2017	0.9795	-	35.07
Flexible Hose	Damage	Lognormal	-	-	-	7.1203	0.2238	0.9799	1268.23	-
	Repair	Normal	0.1125	-3.3718	-	29.958	8.885	0.9768	-	29.95
Air Regulator	Damage	Lognormal	-	-	-	2464.33	0.078	0.9895	2464.33	-
	Repair	Weibull	6.4187	-22.6808	34.2456	-	-	0.9754	-	31.95

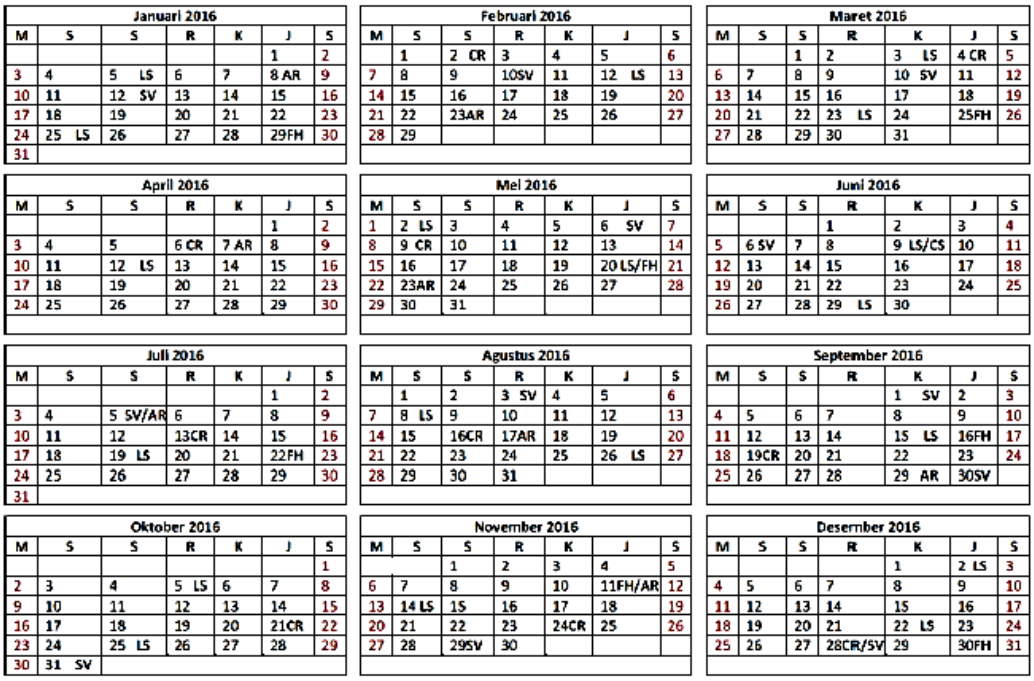

Figure 3. Maintenance Schedule FBW Component Replacement for 2016

3.6 Maintenance Schedule

Maintenance schedule in Figure 3 above is proposed actions to maintenance activities throughout 2016. This schedule is expected to help company reduce the level of breakdown failure or unplanned downtime.

4. CONCLUSIONS AND SUGGESTIONS

4.1. Conclusions

Based on the results of data processing and data analysis that have been done before, there are a couple of conclusions as follow.

a. FMEA analysis provides five highest RPN value which are lies in *Limit Switch* with RPN's value around 336, *Contact Relay* with RPN's value around 210, *Solenoid Valve* with RPN's value around 210, *Flexible Hose* with RPN's value around 144, and *Air Regulator* with RPN's value around 84.
b. LTA analysis provides 5 types of maintenance activities with a number of components as follows.
   - *Scheduled On-Condition Task* for 12 components. Two of them are *Solenoid Valve* and *Flexible Hose;*
   - *Failure Finding Task* for 3 components, namely PCB, *Thyristor* and *Pressure Gauge;*
   - *No Scheduled Maintenance Task* for 5 components, e.g. *Limit Switch, Contact Relay* and *Air Regulator;*
   - *Scheduled Discard Task* for 6 components, e.g. *Timer, Roller* and *Handblock;* last
   - *Scheduled Restoration Task* for 2 components, namely *Suction Filter* and *Motor Induction.*
c. RCM II analysis provides 23 proposed actions to maintain and repair the FBW component machine, one of them is to consider synchronizing the servo amplifier along with the servo valve every overhaul time. this action is done by the maintenance division every 6 months.
d. The realibilty analysis of those 5 components with the highest RPN gives the following results.
   - *Limit Switch* : MTTF value is 306.16 and MTTR value is 33.01.
   - *Contact Relay* : MTTF value is 398.70 and MTTR value is 20.64;
   - *Solenoid Valve* : MTTF value is 558.91 and MTTR value is 35.07;
   - *Flexible Hose* : MTTF value is 1268.23 and MTTR value is 29.95; last
   - *Air Regulator* : MTTF value is 2464.33 and MTTR value is 31.95.

4.2 Suggestions

Based on the research that has been done, gained some suggestions as follows.

a. The application of the proposed action by RCM method can be implemented properly if every party in the company involved in the activities and do their job in accordance with a predetermined schedule.
b. The company proposed to perform the documentation of maintenance process or history with computerized system and use separate software. It aims to facilitate the maintenance analysis to keep company's assets and reduce the risk of losing the maintenance data.
c. The company proposed to always update the data on potential failure's aspects within the production floor in order to overcome the failure in the future.
d. To the study on the same field then expected to conduct reliability analysis and maintenance scheduling along with the cost of maintenance and reparation of each machine.
e. For the study on the same field, further recommended to analyze the inventory, both the needs and the supplies, of the machine's spare parts.

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