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Proposed Policy Preventive Maintenance Machine Moriseiki NH 4000 DCG Method of Reliability Center Maintenance (RCM) And Risk Based Maintenance (RBM) Case Study PT Pudak Scientific

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Abstract — PT Pudak Scientific is a company engaged in the manufacture of aircraft parts industry. Meeting the precise and timely demand of aerospace parts from customers becomes a major corporate responsibility. However, Loss Revenue often occurs due to engine breakdown. So that cause because the production target is not achieved, the product reject, and the delay of delivery. One of the machines that often experience breakdown is Mori seiki NH4000 DCG. Mori seiki NH4000 DCG is the finishing machine for Blank fork End product. The demand for this part is quite large, making it a tough task for the Mori Seiki NH4000 DCG machine. But because the breakdown of the machine is high enough to cause production targets every month are often not met. In addition, Maintenance activities that have not noticed the characteristics of engine damage, as well as the distribution of historical data of the machine causing less effective and efficient actions resulted in substantial Maintenance costs. Based on the results of risk analysis of Mori Seiki NH4000 DCG engine damage, in terms of performance loss system caused by a large enough that is 3.773% of machine production capacity per year. This figure exceeds the risk acceptance criteria by the company that is 2%. Therefore it is necessary to find the appropriate Maintenance policy for the Mori Seiki NH4000 DCG machine. The approach is to use Reliability Centeres Maintenance and Risk Based Maintenance. Based on the above two approaches obtained the appropriate interval time so that the Maintenance activities more effective and can improve the efficiency of treatment by reducing the cost of care previously Rp167.506.286, - per year, to Rp 96.147.061, - per year. With the policy is expected to reduce engine breakdown and performance loss caused. So the number of risks that arise for the future are within the criteria of acceptance set by the company.

Keywords: *Preventive Maintenance, Reliability centered Maintenance, risk based Maintenance, Performance loss*

I. INTRODUCTION

PT Pudak Scientific is one of the growing companies and engaged in manufacturing industry. The company produces aircraft parts that will be rafted at an aircraft assembly company later. In the early stages, pudak company is a company that produces educational props and laboratory equipment. With a strong background of "Engineering Department" In the early years of 2000 PT Pudak Scientific established the CNC Division to continue to support the quality and productivity of the products in production. Started with only 1 CNC machine PT Pudak Scientific continue to do development by investing for new machine procurement. In 2005 PT Pudak Scientific is actively seeking customers and getting some companies that entrust to Pudak to reproduce the components they need. In 2006 Pudak Scientific continues to add high precision turning center machines, achining centers, measuring instruments and high precision gauges. In 2007 PT Pudak Scientific started entering manufacturing for Aerospace products. In 2008 it was awarded the Quality Management System - ISO 9001: 2000 certification within the scope of "The Manufacture of Precision Metal Parts" 2012. Pudak Scientific successfully obtained certification from NADCAP for Aerospace Quality System (AQS AC7004) in 2013. In 2013 Pudak Scientific was awarded the AS9100 Rev .C, which is the Standard Quality Management System for the Aerospace Industries of the world.

Meeting the precise and timely demand of aerospace parts from customers becomes a big responsibility of the company to improve performance from various aspects especially the production and maintenance of the production machine itself. However, conditions in the field are not as easy as schedules and plans that have been arranged. Loss Revenue occurs frequently due to engine damage resulting in Product reject, production targets not achieved, and delivery delay.

The production supervisor says that optimization needs to be done for resources, especially in production machinery facilities. Machines that produce the average Aerospace part produce parts with large lots and work 24 continuously. One such machine is MORISEKI NH 4000 DCG. The NH 4000 DCG MORISEKI machine is used to produce Blank Fork End parts, with 7 different part numbers. Demand for parts that will be in production on this machine is quite large, this makes a heavy task on the machine MORISEKI NH 4000 DCG. However, due to frequent breakdowns or machines stops working, resulting in monthly production targets are not met. MORISEKI NH 4000 DCG production target data and production amount reached from Januari to November.

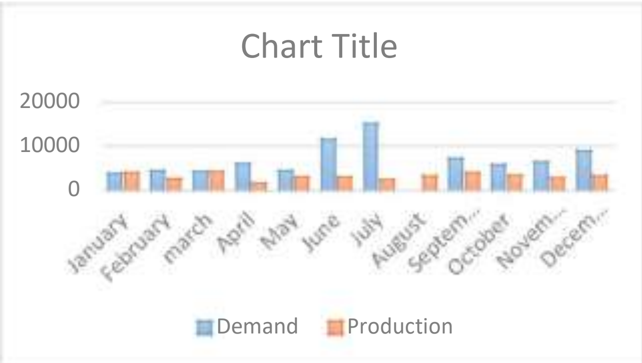

Fig. 1 Demand And Production Reached

The comparison graph shows that from January to November most of the months that did not reach the target of production. This will cause delays in deliveries that impact the Loss Revenue.

Blank Fork End production process through 3 machines that work in series. The first machine processing from raw materials into materials that are ready to be formed the Nakamura Tome machine. The second process is the process pengolaha Blank Fork End Product that is A51nx engine. The last process is finishing using Mori Seiki NH4000 DCG engine. Production process in series in series cause the risk if there is damage to one machine then the production is certain to stop and cause Loss Revenue due to engine downtime. Therefore it is necessary to keep the engine running optimally according to the relibility of the machine under standard conditions. Based on the historical data of the company, data on the damage of three machines as shown in Table 1.

TABLE 1
NUMBER OF MACHINE DAMAGE

Machine Name	Number of Damage
Makino A51nx	67
Nakamura-Tome WT-250 IIMMY	22
Mori Seiki NH4000 DCG DCG	96

Based on the data in Table 1, it can be seen that the Mori Seiki NH4000 DCG machine has the highest damage frequency. This machine serves as a finishing machine for Blank Fork End products. The finishing process is an important process to ensure product preservation is assured. Looking at the data from the table it is necessary to pay more attention to the Mori seiki NH 4000 DCG engine in order to maintain its reliability under standard.

To get effective and efficient maintenance policy for Mori Seiki NH4000 DCG machine can be done with several approaches. One of the best methods to get optimal policy based on damage characteristics, and consider the optimal time interval using Reliability Centered Maintenance (RCM) method. RCM is defined as the process used to determine the exact action taken to ensure that each equipment or fixed asset performs the desired function. RCM can also be used to reduce the cost of maintenance and component failure [1]. Thus, in addition to obtaining an effective care policy, minimum maintenance costs are also generated.

Another method to support policies using RCM is the Risk Based Maintenance (RBM) method. RBM is a quantitative strategy for knowing the risks [2].In deciding the policies adopted by the RBM, consider the reliability and timing of care as well as the risks of the unexpected failure [2].To obtain an effective and efficient maintenance policy for the Mori seiki NH4000 DCG machine, the Reliablity Centered Maintenance and Risk Based Maintenance.

II. STUDY OF LITERATURE

II.1 Maintenance Management

Maintenance is the activity for damaged components or systems to be restored or repaired under certain conditions over a period of time [3]. Maintenance is an activity performed repeatedly with the aim that the equipment always has the same conditions with the initial state.

II.2 Preventive Maintenance

Preventive maintenance is the maintenance schedule performed before the failure occurs, either by replacing the components, or improving the reliability of the components [4]. Assets or equipment are subjected to routine inspection, maintenance and maintenance of facilities in good condition so that no future damage will occur.

II.3 Corrective maintenance

Corrective Maintenance is an improvement done when damage occurs, usually applied when the consequences of damage that occurs do not incur a large cost [4]. Maintenance work undertaken to improve and improve the condition of the facility or equipment so as to achieve acceptable standards. Improvements can be made in such a way, such as changing or modifying the design to make the equipment better.

II.4 Mean Time Between Failure

The time between failures or more commonly known as MTBF (Mean Time Between Failure) is the average time or failure expectation of a component or system (machine) operating under normal conditions [3].

II.5 Mean Time To Repair

Mean Time To Repair (MTTR) is the average maintenance time of one defect until the next maintenance occurs. Here is the calculation of MTTR for each distribution [3].

II.6 Reliability Centered maintenance

Reliability Centered Maintenance is a maintenance approach that combines the practices and strategies of preventive maintenance and corective maintenance to maximize life and asset function, system or equipment with minimum cost [5].

II.7 Schedule On Condition Task

Scheduled on-condition tasks are performed to detect potential failures. Potential failure is an identifiable physical condition and may indicate a functional failure.

II.8 Schedule Restoration Task

Scheduled restoration tasks are an effort to recover the existing components periodically with the aim of restoring the system to its original state. This is done if on-condition tasks are not possible.

II.9 Risk Based Maintenance

Risk Based Maintenance Is a quantitative method of integration between a reliability approach and a risk approach strategy to achieve an optimal maintenance schedule. RBM aims to reduce the risks posed by failures that occur in operating facilities. The quantitative value of risk is the basis for prioritizing maintenance and inspection activities [6].

II.10 Conceptual model

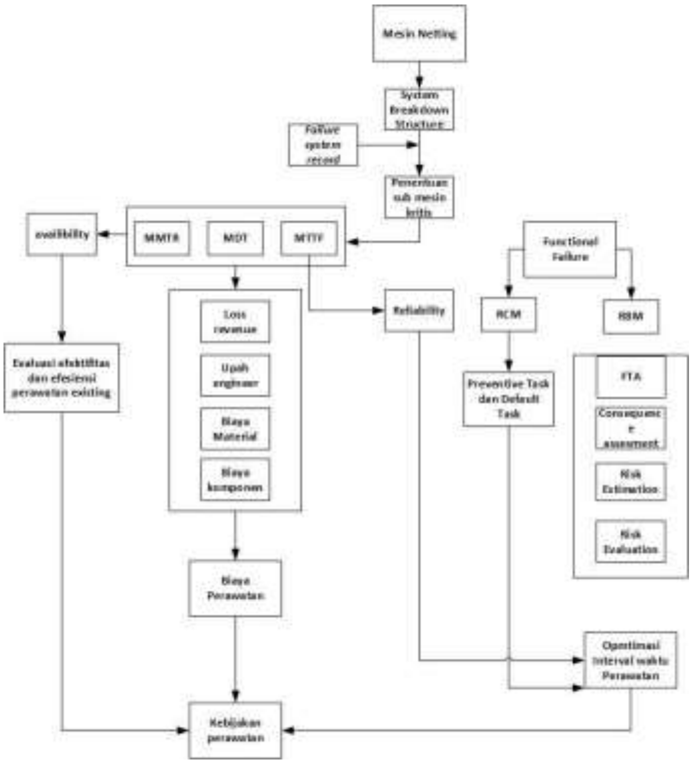

Fig. 2 Conceptual Model

III. Discussion

III.1 Data Collection

At this stage will be collected data needed in conducting research on the final task, the policy proposal Preventive Maintenance MORISEKI NH 4000 DCG engine with Reliability Centered Maintenance and Risk Based Maintenance methods. The data collected is data from MORISEKI NH 4000 DCG machine at PT Pudak Machinary Maintenance Department. MORISEKI NH 4000 DCG machine selection is based on the frekueni damage that occurred in the production machine at PT Pudak Scientific. In the time interval from January 2013 to December 2016 Mori Seiki NH 4000 has the highest historical damage data as much as 95 times.

III.2 Selection of critical subsystems

The selection of critical systems is based on the frequency of damage occurring from 1 January 2013 to 31 December 2016.

TABLE 2
CUMULATIVE PERCENTAGE OF DAMAGE SUBSYSTEM

Subsystem	Number of	percentage	Cumulative
Automatic tool			
hydarulic system	16	0.170	57%
automatic pallet			
coolant system	14	0.138	85%
cooler system	13	0.138	99%
Spindel	1	0.010	100%
total	96		

Based on Table 2 it can be concluded that there are 5 critical subsystems in mechanical system that is, automatic tool change (ATC), automatic pallet change (APC), Hydraulic system, Coolant System, Cooler System. The critical subsystem is chosen because it has a cumulative percentage of 100% that is greater than 80% (based on pareto rule) of total damage.

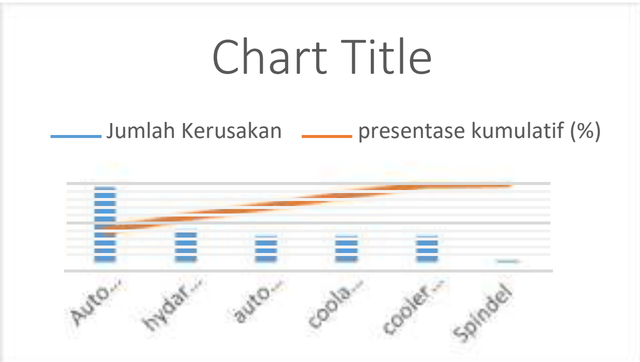

Fig. 3 Pareto chart

III.3 Testing and Determining Distribution Parameters

The distribution test is performed to obtain a representative distribution for each critical subsystem. The distribution test is performed to find the distribution of Time to Repair, Time Between Failure, and Downtime distribution. The distribution test uses the help of Minitab 17.1 software, by looking at the smallest AD value of each tested distribution. As for the determination of distribution parameters using AvSim9.0 in accordance with the distribution representing the subsystem. The results of the distribution test can be seen in Table 3.

TABLE 3
RESULT OF TEST DISTRIBUTION

Subsistem	*Time to*	*Time between*	*Downtime*
ATC system	Weibull	Weibull	Weibull
APC system	Weibull	Weibull	Weibull
Cooler system	Normal	Weibull	Weibull
Coolant system	Normal	Weibul	Eksponensial
Hydraulic			

Reliability is a measure of the ability of a component or equipment to operate continuously without any interruption or damage [3]. Determination of reliability based on the distribution that represents for each subsystem. Reliability is calculated according to the parameters of each distribution. Determination of distribution parameters obtained by using software AV sim + 9. Exponential distribution and normal reliability parameters equal to the value (μ) ie the average failure that occurs within the time interval of historical data damage. As for the reliability parameter subsystem with weibull distribution that is using formula (1).

$$[MTTR = \eta . \Gamma (1 + \quad)]$$

Information :
η = Parameter scale weibull distribution β
= Parameter of weibull distribution form
Γ = gamma table value

The results of the determination of the reliability parameters of each subsitem are available in Table 4.

TABLE 4
RELIBILITY PARAMETERS

		Mean Time	*Mean*
ATC			
APC			
Cooler			
Coolant			
Hydraulic			

III.4 Measurement and analysis with RBM

Measurement with RBM is first to make failure scenario of each critical subsystem and critical component of the subsystem. Functional Failure (FF) is defined as the inability of a component or system to meet the expected performance standards (performance standards) [5]. Function and Functional Failure can be seen on Tabel 5.

III.4.1 Probabilistic failure analysis

Analysis of probable failure is done to determine the probability of failure of each component and subsystem. The calculation of the probability of failure for each component in the subsystem is done for a period of one year machine work hours is 7392 hours. Parameters used in this calculation is the parameters on the test done before. failure functions (distribution) and it has been observed that two-parameter Weibull distribution define them the best.

$$( ) = 1 - \quad \{- ( )\}^{-}$$

The two parameters, η and β, are estimated for the different units and their subcomponents and are presented in Table 6.

III.4.2 System Performance loss

After probabilistic failure is obtained then then do the calculation of the consequences of damage to the component disubsistem critical. The potential consequences of potential hazards are estimated by determining the impact of failure on human life, the environment and economic benefits [7]. From the results of the observation data damage on the machine Moriseiki NH4000 DCG only affects the system performance loss and does not provide a significant impact on human health loss and environmental loss. So the calculation of consequence is only done on system performance loss by using Equation Below.

System Performance Loss = (Mean Downtime x Loss Revenue) + (MTTR x Engineering Cost) + Material cost + Component Cost

III.4.3 Risk Estimation

To obtain the probabilistic risk of emerging can be calculated using equation (3). Risk analysis is a technique used to identify possible events, assess how likely they are, and evaluate potential consequences. As a result, risks can be estimated qualitatively or quantitatively for certain failure scenarios [8].

Risk=Probability of Failure × System Performance Loss

III.4.4 Acceptance Criteria

The next step after the recapitulation of consequences and risks, namely Preparation of risk assessment criteria due to damage MORISEKI machine NH 4000 acceptance criteria conducted through interviews with the head Maintenance PT Pudak Scientific. PT Pudak Scientific is a company engaged in the manufacture of aircraft parts. Therefore, the resulting product must have a high degree of precision. PT Pudak Scientific itself determined that the acceptance of risk due to mesn damage is about 2% of production capacity. From the calculation result obtained risk value generated big enough that is equal to Rp 286.891.212 in interval 1 year. Capacity of machine production is calculated based on hourly rate for one year with calculation as in Table 8.

TABLE 5
FUNCTION AND FUCNTIONAL FAILURE (a)

SUBSYSSTEM	COMPONENT	FUNCTIONAL FAILURE	EFFECT OF FUNCTIONAL FAILURE
	Arm Hand	Arm hand does not grip, and spins, magazine doors can not open	
	Tool post		
	sensor magazine		
	magazine		

TABLE 5
FUNCTION AND FUCNTIONAL FAILURE (b)

SUBSYSSTEM	COMPONENT	FUNCTIONAL FAILURE	EFFECT OF FUNCTIONAL FAILURE
APC	Sensor APC		APC is not working and the machine is not
	Ball screw		Table shift is not smooth
	motor		Alarm machine, and down machine
COOLER	Heat exchanger		Alarm machine, due to overheating
	fan	The wind is not sucked into	The engine becomes hot fast, and the engine alrm
	hose cooler	Liquid does not flow, or leak	The liquid quickly runs out, alrm on the machine
	sensor suhu	Engine temperature is not detected	Undetectable fluid and alrm on the machine
HYDRAULIC	pump motor	Hydraulic fluid does not flow	Fluid does not flow
	hose hydraulic	Liquid flows out due to leaking	The liquid quickly runs out, alrm on the machine
	sensor level	Fluid availability level undetected	Undetectable fluid and alrm on the machine
COOLANT	pump motor	Liquid coolant does not flow	Fluid does not flow
	hose for coolant	Liquid coolant flows out	The liquid quickly runs out, alrm on the machine
	sensor level	The cooolant liquid level is undetectable	Undetectable fluid and alrm on the machine
	tank	Cairang coolant quickly runs out, because the tank is leaking	Fluid flows out and quickly runs out

TABLE 6
PROBABILITY OF FAILURE COMPONENT IN SUBSYSTEM

		Distribution Parameter		Probability of Failure
				1.000000E+00
				1.000000E+00
				1.000000E+00
				0.999999997
				0.999999997
				0.999999997
				0.999983694
				0.999983694
				0.999983694
				0.999999999
				0.999999999
				0.999999999
				1.000000E+00
				1.000000E+00
				1.000000E+00

TABLE 7
RISK IN 1 YEARS PERIODE

Subsystem	Component	*System Performance Loss*	Probability of Failure 1	Risk
	Arm Hand	Rp 10.256.695	1.000000E+00	10.256.695
	Tool post	Rp 13.106.695	1.000000E+00	13.106.695
	Magazine	Rp 58.106.695	1.000000E+00	58.106.695
	Sensor APC	Rp 5.393.249	0.999999997	5.393.249
	Ball screw	Rp 6.943.249	0.999999997	6.943.249
	motor	Rp 20.243.249	0.999999997	20.243.249
	Heat exchanger	Rp 42.453.762	0.999983694	42.453.070
	fan	Rp 11.453.762	0.999983694	11.453.575
	Sensor suhu	Rp 7.603.762	0.999983694	7.603.638
	Pump motor	Rp 16.725.811	0.999999999	16.725.810
	Hose hydraulic	Rp 12.525.811	0.999999999	12.525.811
	Sensor level	Rp 11.875.811	0.999999999	11.875.811
	Pump motor	Rp 17.185.835	1.000000E+00	17.185.835
	Hose coolant	Rp 10.985.835	1.000000E+00	10.985.835
	tank	Rp 13.185.835	1.000000E+00	13.185.835
Total				Rp 286.891.212

TABLE 8
PERCENTAGE OF RISK AND ACCEPTANCE CRITERIA

1 Years Periode	***Revenue*/hours**	**Production Machine Capacity**	**Total Risk**	**Percentage of Risk**	**Acceptance criteris**
7392	Rp 1.028.571	Rp 7.603.200.000	Rp 286.891.212	3.773%	2%

III.5 Measurement With RCM

III.5.1 Qualitative measurement of RCM

The qualitative RCM measurement is by analyzing the function and funtional failure of each sub-component and component. Next make failure modes, the consequences of failure and arranged into Failure Mode and Effect Analysis (FMEA). FMEA is a method used to define and study failure models, and potential effects [1]. Results from FMEA are used as inputs for LTA (Logic tree Analysis). The purpose of Logic Tree Analysis (LTA) is to classify failure mode into several categories so that a priority level can be determined in the handling of individual failure modes based on the category [5]. LTA is used to determine the appropriate preventive task for each component through the RCM decision diagram. From the results of the RCM decision diagram, there are two types of precise preventive tasks for subsystems and components on the Moriseiki NH4000 DCG machine that is the schedule on condition and the restoration schedule. Preventive task is later used as a reference to determine the optimal maintenance.

III.5.2 Time Maintenance Interval Schedule on Condition and Schedule Restoration

a. Calculation of time interval for maintenance task Schedule on Condition is ½ from P-F interval from each subsitem or component. Large P-F (Potential Failure) here is the amount of MTBF that has been calculated before.

b. Calculation The interval of maintenance time for maintenance task schedule restoration requires MTBF and MTTR parameters from each subsystem or component. The calculation of intervals with the resortation task schedule takes into account two types of costs. The first cost of repair due to failure that occurs in the components and costs incurred for maintenance. The equation for calculating the cost of repair or replacement due to damage to components using equation (4).

$= \quad + \quad (+)$

Information :

Cf = Repair or replacement costs due to damage to the components of each maintenance cycle.

Cr = Cost of replacement of component damage

Co = Cost of producer loss (hourly rate)

Cw = Labor costunits, clearly state the units for each quantity in an equation.

While for maintenance cost that is by using equation (5).

From the CM and CF results can then be calculated the interval of care time for maintenance task Schedule Restoration with the equation (X) [9].

1

$= \quad \times [(-1)]$

The result of maintenance interval calculation for each component in the subsystem is as in Table 9.

TABLE 9
MAINTENANCE INTERVAL FOR EACH COMPONENT (a)

Subsyst	Component	Maintenance Task	Maintenance
		Schedule on	
		Schedule on	
		Schedule on	

TABLE 9
MAINTENANCE INTERVAL FOR EACH COMPONENT (b)

Subsystem	Component	Maintenance Task	Maintenance
	Sensor	Schedule on	
		Schedule on	
		Schedule on	
System	Heat	Schedule on	
		Schedule on	
		Schedule on	
		Schedule on	
Hydraulic	pump	Schedule on	
	hose	Schedule on	
	sensor	Schedule on	
System	pump	Schedule on	
	hose for	Schedule on	
	sensor	Schedule on	
		Schedule on	

III.5.3 Maintenance Cost

The maintenance policy based on the result of RCM analysis done got two task maintenance proposal that is schedule on condition task, and schedule restoration task. The time interval for each component of the subsystem has been predetermined at the interval of care time. To do the cost of treatment calculation can be used equation.

$= \quad \times$

Information :

TC = Total Cost

Cm = Maintenance Fee

Fm = Frequency of maintenance

Total maintenance cost is calculated for frequency of treatment within one year. The results of the proposed maintenance cost calculation for one year is multiplication between the frequency of care with the cost of each treatment. Total cost obtained is Rp 96.147.061 per year for treatment of the proposal, while for the cost of existing maintenance is Rp 167,506,286. Of the two total costs obtained, the total cost of the proposal is much lower than the total cost of the existing. This is because the existing maintenance policy does not take into consideration the characteristics of critical components and the distribution of damage that occurs in the machine subsystem. So there is less effective and inappropriate treatment performed every month. This results in a lack of maintenance efficiency marked by high maintenance costs incurred.

IV. CONCLUCION

From the calculation results obtained the total risk that arises if the damaged component is Rp 286.891.212 or 3.773% of the production capacity of one year. The value is above the acceptance criteria set by the company that is equal to 2%. Therefor hte company need a policy for maintenance system. Using RCM analysis we get the time interval of maintenance is calculated based on the maintenance task obtained by the schedule on condition and the schedule restoration. The cost of maintenance proposals based on maintenance tasks obtained is more effective and efficient compared to maintenance with existing maintenance task.

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