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Modularity Design Approach for Preventive Machine Maintenance

D Ernawati*, E Pudji, Y Ngatilah, R Handoyo

Industrial Engineering Department, Faculty of Engineering,
University of Pembangunan Nasional “Veteran” Jawa Timur, Indonesia

*diraernawati@yahoo.com

Abstract. In a company, machine maintenance system will be very influential in production process activity. The company should have a scheduled engine maintenance system that does not require high costs when repairing and replacing machine parts. Modularity Design method is able to provide solutions to the engine maintenance scheduling system and can prevent fatal damage to the engine components. It can minimize the cost of repair and replacement of these machine components. The paper provides a solution to machine maintenance problems. The paper is also completed with case study of milling machines. That case studies can give us a real description about impact implementation of modularity design to prevent fatal damage to components and minimize the cost of repair and replacement of components of the machine.

1. Introduction

The increasing competitive pressure caused by market globalization requires every company to improve the efficiency and effectiveness of its operational activities. Therefore, in order for the operation process can run smoothly, it is necessary to main maintenance of machine periodically in order to support the reliability of a machine to be able to function well and optimally and able to reach production target.

Modularity Design is a method that can be used for preventive measures, reduce the possibility of severe damage to the machine, reduce maintenance time and reduce maintenance costs. This method uses grouping of machine based on component downtime value or component function in hopes can simplify the turn of machine parts, increase maintenance time, and can reduce maintenance cost. Preventive maintenance has a close relationship with reability and maintainability engineering. OEE calculations (Overall Equipment Effectiveness) are used to measure the effectiveness of an entire machine.

This paper uses case study in X company which is currently experiencing problems in terms of frais machine maintenance. During this time the company doing maintenance frais machine by directly replacing the damaged engine components without proper maintenance scheduling and the costs are also still very high. So that the maintenance of the machine periodically with modularity design method is expected to provide solutions to the problem. Precise machine maintenance scheduling can prevent fatal damage to machine components so as to minimize the cost of repair and replacement of the machine components.



2. Literature and Method

Machine maintenance is a common issue between maintenance and production, because maintenance is considered a waste of money, while production parts feel damaging but also make money. Maintenance is an activity to maintain factory facilities and make necessary repairs or adjustments in order to have a satisfactory state of production operation in accordance with what is planned. Therefore, much needed maintenance activities that include maintenance and maintenance of machinery used in the production process. Maintenance is a combination of various actions taken to keep an item in, or fix it until an acceptable condition. For definition maintenance is more obvious is the act of maintaining a machine or equipment factory with renewal life and engine failure / failure. Maintenance is all activities involved in keeping a system's equipment in working order [1]. The meaning is maintenance is any activity in which is to keep the equipment system to work properly. Maintenance is a work performed sequentially to maintain or improve existing facilities so as to comply with standards (in accordance with functional standards and quality) [2].

Less attention to maintenance among others, caused by the amount of funds needed, and the complexity of maintenance tasks. But for the operation of the company, maintenance has become a dual function, namely the implementation and awareness to perform maintenance of production facilities. There was a lot of research that concern about development in maintenance theory and practice, and in information technology and decision support models [3]. However, in order to be able to make rational and justifiable tactical decisions concerning maintenance, one needs to have a clear idea of what the advantages and disadvantages of each maintenance policy are. In addition, a supporting maintenance concept is required [4]. The issues related to industrial maintenance were studied through a survey instrument. The survey questions included collaboration between the maintenance and other functional areas likely sources of maintenance problems [5]. Maintenance analysis during the design, acquisition, and selection phase ensures that maintenance requirements are minimized in the future [6].

High value products are typically technology intensive, expensive and reliability critical requiring continuous maintenance throughout their life cycle. Continuous maintenance in an engineering service that allows products to achieve required performance through life with optimum through live cost. Examples of the high value products include high tech machine tools, aircraft engine, defence equipment, etc [7]. Preventive maintenance is also called preventive or overhaul, which is maintenance activities to prevent unexpected damage and find the conditions or circumstances that cause operating facilities more appropriate. Preventive maintenance is a scheduled maintenance, generally periodically, where a set of maintenance tasks such as inspection and repair, replacement, cleaning, lubrication, adjustment and equation are made [8]. Preventive maintenance is very appropriate, because its usefulness is very effective in facing the production facilities which are included in critical unit, that is equipment or facility that endangers health and safety, affect the product, can cause congestion of whole process of production, and when capital is planted for this facility is relatively more expensive. Maintenance problems are crucial aspect of nowadays industrial problems. However, the quest of the efficient periodicity of maintenance for all components of a system is far from an easy task to accomplish when considering all the antagonistic criteria of the maintenance and production view of a production system [9]. Prescriptive maintenance planning is an essential enabler of smart and highly flexible production processes. Due to increasing complexity, traditional maintenance strategies lack in fulfilling present day production requirements [10]. OEE (Overall Equipment Effectiveness) is a comprehensive measure used to identify performance levels or engine efficiency levels. If you go to the production floor, the common problem that is often encountered is that the production equipment is not operating properly, affecting other processes. This OEE measures whether the production equipment is working normally or not. OEE highlights 6 major losses (cause six production losses are not operating normally) [11].

Mean Time To Failure (MTTF) is the average time of failure of a system (component). For a repairable system, the MTTF is the lifetime of a component when it is first used or powered on until the unit is damaged again or needs to be re-checked. Mean Time To Repair (MTTR) is the average time for the time of checking or repair when the component or unit is checked until the component or unit is used.

Mean Time to Failure (MTTF) is :

$$\begin{aligned} E[T] &= \int_0^{\infty} t \cdot f(t) dt \\ &= - \int_0^{\infty} t \frac{dR}{dt} dt = -tR(t)|_0^{\infty} + \int_0^{\infty} R(t) dt \end{aligned} \quad (1)$$

Mean Time to Repair (MTTR) is :

$$E[T] = \int_0^{\infty} R(t) dt \quad (2)$$

Total maintenance cost :

$$\begin{aligned} TC &= C_f f_F + C_M f_m \\ &= C_f \left| \frac{1}{TM} \int_0^{TM} \lambda(t) dt \right| + C_M \left| \frac{1}{TM} \right| \\ &= \frac{1}{TM} \left| C_F \int_0^{TM} \lambda(t) dt + C_M \right| \end{aligned} \quad (3)$$

If the weibull distribution is known, the total cost per hour is:

$$TC = \frac{C_F}{\eta^\beta} TM^{\beta-1} + \frac{C_M}{TM} \quad (4)$$

To obtain the minimum total cost then $\frac{dT_c}{dT_M} = 0$ so obtained

$$TM = \eta x \left| \frac{C_M}{C_F(\beta-1)} \right|^{\frac{1}{\beta}} \quad (5)$$

Tc = Total maintenance cost

C_f = Repair cost per cycle

f_F = Failure frequency

C_M = Maintenance cost per cycle

f_M = Maintenance frequency

T_M = The optimal maintenance time interval in hours

Analyzing and revising current machine tools with regard to their maintenance friendliness, servicing and inspection activities leads to a split up between production and maintenance responsibilities [12]. Modularity design is a concept commonly used in the process of designing a product and this concept will be adapted into the maintenance system. Modularization is to classify the product in the form of a different unit based on its function to facilitate transfer and replacement. With a modular system, the system can produce profitable techniques and solutions in the factory economy. Modular development only begins when initially understood as an individual product or a distance measure and on this development is expected to produce a large number of variants. Modularity allows for a deduction of service costs by grouping components based on similiary and dependency, making it easier to perform repair and maintenance. It is expected that every function in a product is independent of other functions. The reduction and standardization of the interfaces between the modules can also reduce the interdependencies between the activities for installing the building components, which are currently carried out by different subcontractors [13]. Modular design as a modern design methodology can

respond to market changes rapidly. At the same time, it is able to shorten product design and manufacturing cycle, improve product quality and reliability, and facilitate product disassembly and remanufacturing [14]. Modular design can address the need for a high number of product variants and further allow a higher degree of automation in the assembly line [15]. One of the benefits of modular design is ease-of-service.

This research begins with taking the necessary data on X company. Method of data retrieval is done by interview and observation. The sequence of data processing used in this research is (1) Determination of critical machine group, (2) Calculation of OEE value, (3) determination of component causing biggest downtime, (4) Calculation of time interval of component damage, (5) , (6) Calculation of treatment time interval, (7) Maintenance cost calculation, (8) Comparison of proposed total cost with company total cost. The result of this improvement proposal is a comparison between actual repair activities and activities after using the new preventive methods. From the results of data processing until the calculation of time interval prevention and subsequent examination made a proposal scheduling preventive and inspection improvement activities for components that are expected to be applied by the company. Then ending with the proposed cost savings with modularity model machine scheduling will be less if the maintenance cost is not minimized as well, then the next will be given the proposed cost savings company maintenance using modularity design method will be applied at the time of replacement of machine components.

3. Results and Discussion

Overall Equipment Effectiveness value for machine frais obtained from calculation is equal to 83,9%.

Based on the data processing obtained several modules as follows:

Module 1: Dynamo Bearing + Top Spindle Bearing + Bottom Spindle Bearing + Bearing Axle Input + Bearing Axle Output + Transmission Axle Bearings

Module 2: Pinion Gear + Input Shaft + Output Shaft + Transmission Shaft + Clutch Gear

Module 3: Spindle Hub Sleeve + Gearbox Hub Sleeve + Clutch Hub

Module 4: Coils + Terminal Box + Shift Lever

Table 1. Maintenance interval

Component	β (Shap)	η (Scale)	C_M (Rp)	C_f (Rp)	TM (hour)
Spindle bearing	2,97646	63326,4	4.701.739,278	13.349.632,73	1240,66
Gear box	1,83358	115744	4.852.683,245	11.968.460,35	2179.07
Motor dynamo	1,75800	190989	5.837.970,203	11.856.995,15	4325,9
Arbor	2,40052	141248	1.841.353,05	3.993.532,05	3176,9
Coolant Hose	6,92834	103669	773.654,234	2.000.249,745	2137,48

From table 1, the maintenance intervals for the frais machine components include Spindle bearings for 1240.66 hours or 51 days, for Gear boxes for 2179.07 hours or 90 days, for motor dynamo for 4325.9 hours or 180 days, Arbor for 3176.9 hour or 132 days and for coolant hoses for 2137.48 hours or 89 days.

Table 2. Comparison of proposed total cost and company total cost

Component	Proposed TC (Rp)/month	Company TC (Rp)/month	Efficiency %
Spindle bearing	757.957,75	1.000.000	24,2
Gear box	1.679.120	1.900.000	11,62
Motor dynamo	270.609,2	350.000	22,68
Arbor	115.949	175.000	33,74
Coollant hose	76.304,2	155.000	50,77
Total	2.899.958,15	3.580.000	18,99

From the results of the cost of treatment proposals on each component is then based on Table 3 obtained cost of treatment proposals on frais machine that is Rp 2.899.958,15 more 18.99% of the total cost of treatment at the company amounting to Rp 3.580.000. From table 3 it can be seen the comparison between proposed TC and company TC, where the costs incurred by proposed TC fewer than the cost at the company TC in each month which means the method of maintenance can be accepted.

4. Conclusion

In this paper, we propose a modularity design model for preventive machine maintenance that periodical maintenance of the machine with modularity design method was able to provide solutions to the problem. Precise machine maintenance scheduling can prevent fatal damage to machine components so as to minimize the cost of repair and replacement of the machine components. Based on the calculation of data processing obtained maintenance intervals for the components of the milling machine such as Spindle bearings for 1240.66 hours or 51 days, for Gear box for 2179.07 hours or 90 days, for motor dynamo for 4325.9 hours or 180 days, Arbor for 3176.9 hours or 132 days, for Coollant hose for 2137.48 hours or 89 days. Scheduling planned maintenance can maximize the life of a component by performing value added activities on machine components. The results of the research are expected to be applied to the company concerned to improve the engine maintenance scheduling system.

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