Preventive Maintenance Modeling on Die Casting Machines with Information Systems

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Abstract

From the results of observations at the company, the main problem found is that maintenance activities have not been carried out properly due to the tight production schedule. It is the reason for replacing components, only when the machine is damaged suddenly. The purpose of the study is to determine the type of machine that requires periodic maintenance, and critical components, along with how much reliability if applied through an information system. The case study method carried out is a quantitative method by processing data according to preventive maintenance. The analysis is carried out by determining the engine and critical components and then calculating the meantime to failure (MTTF) and mean time to repair (MTTR) to get the value of age replacement, availability, reliability, and downtime. The results achieved are increased availability and reliability and decreased total downtime by implementing proposed preventive maintenance for ladle, auto spray and heater components.

Keywords –
Risk, procurement, supply chain, failure mode effect analysis, mitigate risk, scrm

1. Introduction

Various efforts were made by manufacturing companies to improve performance, by conducting timely production processes, controlling raw material supplies, and distributing products to distributors on time, thus improving service to customers. The production process was based on good scheduling, material control to prevent the occurrence of material running out, product distribution according to the needs of distributors and customers. These efforts could be achieved, if supported using information technology to record sales orders from distributors, stock inventory of materials, the creation of purchase orders to suppliers, and in the creation of financial statements within the company.

The use of computers could display accurate information for the company, thus reducing the occurrence of problems in the production process. For example, checking the availability of materials by factory employees who were previously manual, could use the electronic supply chain (e-SCM). By implementing e-SCM, activities ranging from goods production, controlling of raw material supplies, distributing of goods, and forecasting or innovating of new products, were carried out computerized and online. This technology was used by companies collaborating with suppliers to exchange raw material data, and others online.

In manufacturing companies, the smoothness of the production process affects the achievement of their targets. To achieve good performance, machines must have a maintenance system so that they can have optimal operation when used (Basri et all., 2017). However, in practice, many manufacturing industries still focus more on the production process and pay less attention to preventive measures to reduce machine damage during the production process.

The object studied here is a company engaged in the automotive industry, which produces various motorcycles ranging from cub type, scooter to sport type. In the maintenance and repair management system, the activities are scheduled every month in the first week and are adjusted to the production schedule (Angius et all., 2016). The tight production schedule causes maintenance activities to get less priority. Replacement of components is often only done when there is a sudden machine breakdown during the production process. 16 Die Casting machines have an essential role in producing Crank Case R, Crank Case L, and Cylinder Comp components in the Die Casting department. The maintenance management system that is not implemented regularly cause many die casting machines to experience disturbances when operated. It is why it is essential to implement a preventive maintenance system in the company's production process.

Maintenance of damaged components is carried out regularly to prevent damage and minimize machine downtime. With the development of increasingly advanced technology, the problem's solution will be supported by developing information system applications. The application helps to process machine breakdown data automatically and to calculate the right time to perform maintenance (Ab-samat et all., 2012).

The formulation of the problem is to determine how long it should take for inspection, maintenance, and replacement of components before the component is damaged, determine which machine has the highest breakdown frequency and critical components that cause it, and find out if there is an increase in reliability of critical components by implementing maintenance prevention (Zahedi and Salim, 2016) (Hardt et all., 2021). From the formulation of the problem, several objectives can be achieved, including finding out the machines and components with the highest downtime, the magnitude of the increase in the reliability of critical components, and providing information related to preventive maintenance activities through the application of information systems (Purnama, C., 2019).

2. Literature Review

Preliminary research is the first step carried out to get an overview of the general conditions that are happening in the company so that later problems can be identified (Duarte et all., 2006). This initial step is carried out by direct observation to the company, starting from the observation of the factory to the observation of the Die Casting department. After completing the observations, proceed with conducting interviews or interviews and brainstorming with the maintenance department to identify current problems in the company (Qian and Dong, 2017). This interview and brainstorming result are the determination of the problem formulation and objectives related to preventive maintenance.

The next step is to collect data, especially data on engine damage and die casting components for January 2019 to December 2020, and data on repair and operational costs. The data that has been collected is then processed by calculating the value of age replacement, reliability, availability, downtime, and total—then analyzed by comparing the value of age replacement, reliability, availability, downtime, and total costs before and after the proposed preventive maintenance activities. From the results of this preventive maintenance analysis, a machine maintenance information system is designed to support preventive maintenance activities in terms of data collection, machine performance calculation, and information related to the machine breakdown.

3. Methodology

The methodology in this research is descriptive analytic. Research is carried out in the unit in charge of procurement and storage. Figure 1 describes the sequence of activities in this study.

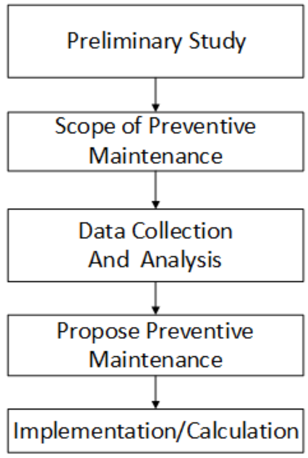

Figure 1 Methodology Research

Preliminary study process is carried out to find out the problems and what parts are related to the problem. After the data from the initial observations are obtained and already know the existing problems, the next step is to define the problem formulation in detail to minimize the scope discussed in this case study. The problems discussed are about maintenance intervals and the repair time.

Scoping of Preventive Maintenance, study was conducted to find and obtain both articles and theories related to the problems discussed, namely preventive maintenance. The literature search focused on preventive maintenance and some supporting things such as searching for data distribution, mean time to failure, mean time to repair. After that, data collection that can support the process of solving this problem is carried out. Collected data such as business processes, breakdown interval data and repair duration.

After the data is collected, proceed to the data processing process. The data is processed into information that can support the complete process and can also meet the needs of the analysis carried out. Existing problems are solved by using preventive maintenance with the age replacement method. The analysis results carried out are also used in the design of information systems to facilitate the running process.

After data processing is done, system design is carried out to design a system that can help the preventive maintenance process. Finally, conclusions are made that can answer the formulation of the problem and provide suggestions for developing the company processes and case studies.

4. Result And Discusion

The measurement of active maintenance time includes time to study the damage that has occurred and data on the damage that has occurred to calculate the correct maintenance time and duration. Preventive maintenance performs simple preventive maintenance actions such as lubrication, cleaning or checking for existing problems. This treatment time can be measured by using the time when performing maintenance activities within a specific frequency[6]. PM has scheduled downtime, usually periodically, consisting of several sets of activities, such as inspection and repair, replacement, cleaning, oiling, and alignment.

Calculation

The Die Casting-07 machine is a critical machine because it has the highest breakdown frequency among other machines. Damage data can be seen in Table 1.

Table 1 Die Casting Machine Downtime Data 2019 - 2020

No.	No. Machine	% Downtime	% Cumulative

		Total Downtime (minutes)		
1	DC-07	5745	12,20	12,20
2	DC-12	4125	8.76	20.96
3	DC-19	3885	8.25	29.21
4	DC-16	3635	7.72	36.93
5	DC-18	3582	7.61	44.53
6	DC-13	3360	7.13	51.67
7	DC-14	3260	6.92	58.59
8	DC-11	3160	6.71	65,30
9	DC-09	2545	5.40	70,70
10	DC-06	2520	5.35	76.05
11	DC-20	2335	4.96	81.01
12	DC-01	2100	4.46	85.47
13	DC-15	1950	4.14	89.61
14	DC-04	1670	3.55	93.16
15	DC-08	1625	3.45	96.61
16	DC-02	1597	3.39	100.00
	TOTAL	47094	100%	

After determining the critical machine, on the Die Casting-07 machine there are several components that often experience damage so that it interferes with production activities. Determination of critical components is done by tabulating the damage data of these components into a Pareto diagram which can be shown in Figure 2.

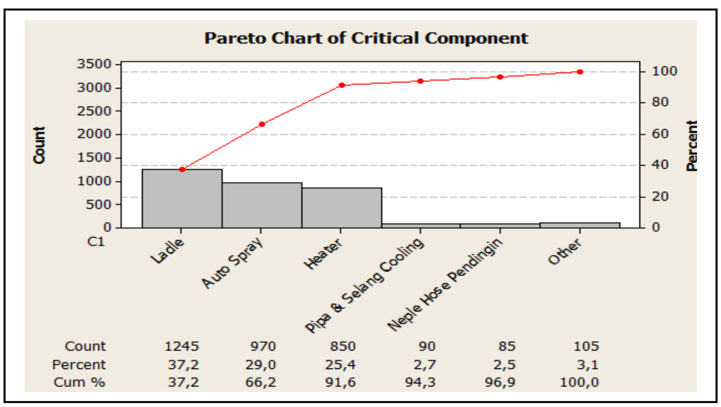

Figure 2. The critical components of damage

After knowing the engine and critical components, the calculation is continued by calculating the time between damage (time to failure) and repair (time to repair). Furthermore, table 2 are the selected distribution is determined by calculating the index of fit and performing a distribution suitability test so that the parameters of each critical component can be calculated to obtain the meantime to failure (MTTF) and table 3 is the mean time to repair (MTTR) calculations.

Table 2. Recapitulation of MTTF Values for DC-07. Engine Components

Component	Preferred Distribution (TTF)	Parameter	MTTF Value
Ladle	Lognormal	tmed = 62,606	132,988

		s = 1.2275	
Autospray	Lognormal	tmed = 182,363	595,421
		s = 1.538	
heater	Weibull	θ= 240,062	341.57

Table 3 Recapitulation of MTTR Values for DC-07. Engine Components

Component	Preferred Distribution (TTR)	Parameter	MTTR value
Ladle	Lognormal	tmed = 0.279 s = 0.8033	0.3853
Autospray	Lognormal	tmed = 0.305 s = 1.357	0.768
heater	Lognormal	tmed = 0.3256 s = 1.265	0.725

Determining the interval of time for replacement of damage prevention, the method used is age replacement by trial and error to calculate the replacement time of prevention of damage based on the optimal replacement age with the minimum downtime value.

The results of the preventive replacement time interval calculation for each component can be seen in table 4, with one example of the calculation shown by the ladle component, which can be seen in table 5.

Table 4. Calculation Results of Damage Prevention Replacement Time Interval

Component	Preventive Replacement Time Interval (hours)
Ladle	108
Autospray	506
heater	320

Table 5 Calculation of Ladle Component Replacement Time Interval

tp (hour)	F (tp)	R (tp)	M (tp)	D (tp)	A (tp)
50	0.420969861	0.579030139	315.9086014	0.00237364	0.99762636
60	0.48495997	0.51504003	274.2246952	0.00234545	0.99765455
70	0.539434957	0.460565043	246.5320393	0.00232651	0.99767349
80	0.586067931	0.413932069	226,9156748	0.00231428	0.99768572
90	0.62623789	0.37376211	212.3601943	0.00230702	0.99769298
100	0.661057778	0.338942222	201.1745484	0.00230350	0.99769650
108	**0.685668609**	**0.31433139**	**193.953753**	**0.00230276**	**0.99769724**
109	0.68856407	0.31143593	193.1381635	0.00230278	0.99769722
110	0.691421632	0.308578368	192.339947	0.00230282	0.9976972
113	0.699773343	0.300226657	190,0443927	0.00230306	0.99769694
114	0.702485666	0.297514334	189.3106244	0.0023031870	0.99769681

At this company, preventive maintenance activities are carried out based on the experience of previous machine breakdowns and Original Equipment Manufacturer (OEM). However, according to Labib (2004), preventive maintenance should be based on the machine's condition. It is because each machine is operated in a different environment, and the predictions of the OEM cannot describe the damage of the machine. Therefore, preventive maintenance activities need to consider the condition of the current machine concerning internal factors, namely the age of the component, using the Age replacement method, which aims to reduce costs, minimize machine downtime, and improve reliability and availability.

Implementing preventive maintenance based on the age replacement method will support more effective maintenance decision-making. It can be seen from the increase in the reliability value for the three components (ladle, auto spray and heater) with an average increase of up to 100% or a twofold increase from the previous reliability value, which can be seen in Table 6. downtime of 2,258 hours, which provides benefits for the company from the production side as shown in Table 7. Finally, if calculated from the cost factor, it produces an average savings of 18.95% for the three components. It can be seen in Table 8.

Preventive maintenance activities based on the age replacement method make component replacements carried out before the component is damaged. It means that the replacement frequency is more frequent than before, but this is still acceptable considering that this approach provides significant operational and financial benefits if carried out regularly and periodically.

Table 6 Comparison of Reliability Before and After Preventive Maintenance Activities

Component	**T (hour)**	**MTTF (hours)**	***Reliability* Before Preventive Maintenance**	***Reliability* After Preventive Maintenance**	**Improved Reliability**
Ladle	108	132,988	0.269664738	0.518940464	92.44%
Autospray	506	595,421	0.220930712	0.506482039	129.25%
heater	320	341.57	0.271103613	0.48818424	80.07%

Table 7 Comparison of Average Total Downtime Components Before and After Preventive Maintenance

Preventive Maintenance	***Downtime* (o'clock)**	**Saved Time**	**%**
Total Downtime Before PM (hours)	4,258	4.258 – 2.5 = 2,258 hours	(2,258 / 4,258) * 100% = 53.04%

Table 8 Total Costs Before and After Proposed Preventive Maintenance

Component	**Before Preventive (per month)**	**After Preventive (per month)**	***Cost Saving***	***Cost Saving* (%)**
Ladle	Rp 6,567,526	Rp 4,943,160	Rp 1,624,366	24.73
Autospray	Rp 1,101,376	Rp 758,792.54	Rp 342,584	31.11
heater	Rp 2,030,057	Rp 1,240,320	IDR 789,738	38,90

Information System Design

The information system is designed, starting with making a business model, both for preventive maintenance and corrective maintenance activities, which are described through activity diagrams. Furthermore, system functions are tailored to the company's business needs using tools, namely *use case diagrams* and *domain model class diagrams*, which can be seen in Figure 3.

Figure 4 Use Case Diagram

From the design of system functions made, a user interface is designed to connect the interaction between the user and the system in carrying out tasks. The following is an example of the interface for the Preventive Maintenance Scheduling Form.

Moreover, after the interface is made, the last step is to plan how the designed system will be implemented and operationalized, described through the deployment environment and software architecture in Figure 7 and Figure 8.

5. Conclusion

Based on the calculation of preventive maintenance, it was found that the die casting machine-07 is a binding machine with selected critical components ladle, auto spray and heater. In addition, it is known that preventive maintenance actions, especially replacement of damage prevention, are carried out after the ladle component reaches a service life of 108 hours, the auto spray component is 506 hours, and the heater component is 320 hours. Moreover, by performing preventive maintenance, the reliability curve of the ladle component shows an increase of 92.44%, auto spray 129.25%, and heater component 80.07%. The application of information system applications can support engine maintenance activities in terms of data collection and calculation of engine and component performance.

The company should pay more attention to the DC-07 engine and its components to keep the engine performance always in normal condition.

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References

Ab-samat, H., L. N. Jeikumar, E. I. Basri, N. A. Harun, "Effective Preventive Maintenance Scheduling : A Case Study," *Proc. 2012 Int. Conf. Ind. Eng. Oper. Manag. Istanbul, Turkey*, pp. 1249–1257, 2012.

Angius, A., M. Colledani, L. Silipo, A. Yemane, "Impact of Preventive Maintenance on the Service Level of Multi-stage Manufacturing Systems with Degrading Machines," *IFAC-PapersOnLine*, vol. 49, no. 12, pp. 568–573, 2016, doi: 10.1016/j.ifacol.2016.07.696. 2016

Basri, E.I., I. H. A. Razak, H. Ab-Samat, S. Kamaruddin, "Preventive maintenance (PM) planning: A review," *J. Qual. Maint. Eng.*, vol. 23, no. 2, pp. 114–143, doi: 10.1108/JQME-04-2016-0014. 2017

Duarte, J.A.C., J. C. T. A. Craveiro, T. P. Trigo, "Optimization of the preventive maintenance plan of a series components system," *Int. J. Press. Vessel. Pip.*, vol. 83, no. 4, pp. 244–248, doi: 10.1016/j.ijpvp.2006.02.016. 2006

Hardt, F., M. Kotyrba, E. Volna, R. Jarusek, "Innovative approach to preventive maintenance of production equipment based on a modified tpm methodology for industry 4.0," *Appl. Sci.*, vol. 11, no. 15, 2021, doi: 10.3390/app11156953. 2021

Purnama, C., "Analyze Machine Maintenance Cost With Corrective Method and Preventive Method To Increase Production Result," *Int. J. Bus. Rev. (The Jobs Rev.*, vol. 2, no. 1, pp. 1–8, 2019, doi: 10.17509/tjr.v2i1.15307. 2019

Qian, F., K. Dong, "The Open Cybernetics & Systemics Optimizing Preventive Maintenance of Used Equipment for Lease Abstract :," no. Cm, doi: 10.2174/1874110X0171101008 2017

Zahedi, Z., A. Salim, "Integrating Preventive Maintenance Scheduling As Probability Machine Failure And Batch Production Scheduling," *ComTech Comput. Math. Eng. Appl.*, vol. 7, no. 2, p. 105, doi: 10.21512/comtech.v7i2.2247. 2016

Biography

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