

Maintenance Scheduling On Printing Machine Using The Duane Model

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Abstract: The important thing to ensure the success of operations is increasing reliability, which is achieved by maintaining machines and equipment. The Duane model is an approach in determining the MTBF (mean time between failure). The Duane model modifies the MTBF data into a logarithmic form. This paper chose the printing machine as the object of this study. The conventional method uses the MTBF data distribution pattern to obtain the average operating time. Using the Duane model and conventional method resulted a relatively small difference, 2.5 hours.

Index Terms: reliability, maintenance, printing, machine, Duane, model, conventional, method.

1. INTRODUCTION

Maintenance of components or equipment using reliability analysis aims to optimize the trade-off between maintenance costs and production stability. The main thing is to determine when the maintenance or replacement of the components. Therefore, the ability to predict the time interval of failure is needed. Reliability analysis is usually done by comparing the failure data pattern to a mathematical model. Accuracy in predicting and calculating requires a lot of new data and collected from appropriate sources.

2. DUANE MODEL

Maintenance activities carried out at a certain time, will affect system performance, of course, the duration of the next failure [1],[2]. In general, the time between failures will be longer, proportional to the associated maintenance costs. Can be written x_t affects x_{t-1} , affects x_{t-2} , etc. In other words, any relation between the sequential data [3],[4]. Previous data affects the next data. One of mathematical model that suitable for modeling the time between failures, with monotonous fluctuation (tend to fixed trend pattern), is the Duane Model. Duane stated that failure data of different systems, was the cumulative MTBF versus cumulative operating time, formed a straight line when plotted on log-log paper [5].

3. CASE STUDY: PRINTING MACHINE MAINTENANCE

In this study, we used the data of printing machine failure as research objects. Figure 1 contains a plot of time data between the failure on the printing machine, as the object of this study.

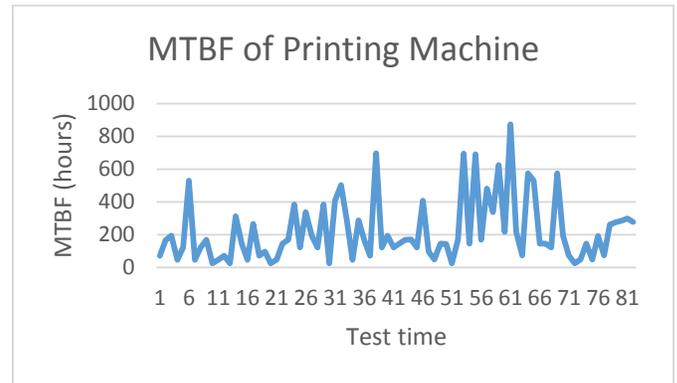


Figure 1. Plot of MTBF of Printing Machine

In figure 1, we can see that the MTBF data is monotonous fluctuated so we can apply the Duane model. There are 82 MTBF data, we use the first 77 data to determine the maintenance schedule, and 5 other data for the evaluation process, as well as to validate the model. Duane's model use $N(T)$ as the number of failure at time T ; and mean time between failures is $MTBF_c$. So

$$MTBF_c = \frac{T}{N(T)} \dots \dots \dots (1)$$

which is can be expressed as:

$$\ln(MTBF_c) = \alpha \ln(T) + \ln b \dots \dots \dots (2)$$

So, we need to plot the transcendent equation to get the logarithmic data pattern. In figure 2, we get that data are linear, especially from number eight or number nine to the last data.

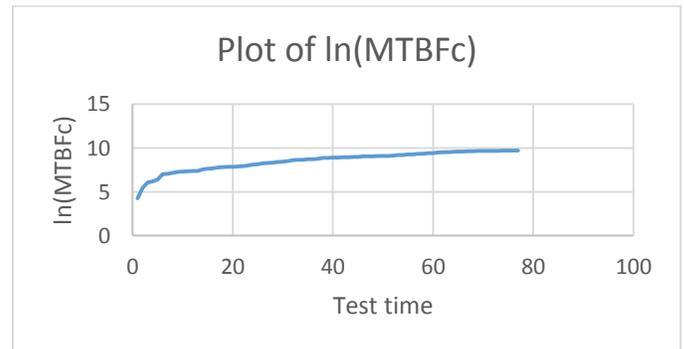


Figure 2. Logarithmic Data Pattern

Then equating $MTBF_c$ to its expected value, and assuming an exact linear relationship, gives:

$$E(MTBF_c) = b T^\alpha \dots \dots \dots (3)$$

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Based on Figure 2, we make a little trial-and-error in choosing the starting point used to construct the regression equation. Using Minitab 19, we calculated four regression equations with some changes in data usage. The first equation is obtained by processing all data, from the first data to the 77th. The error generated by this equation is relatively very large. This is caused by non-linear data pattern. Figure 2 shows that the data is not linear, especially in some initial data. It shows that the data forms a linear pattern starting at the 6th data. The other equations are obtained by changing data usage. We use data number one, number two, number eight, number nine, number ten, number eleven, and number twelve as the first to get these equations. Table 1 contains those regression equations, along with their error calculations, respectively.

Table 1. Regression Equations for Ln(MTBFc)

Starting Data Number	Regression Equation for Ln(MTBFc)	Mean Squared Error (MSE)	Mean Absolute Error (MAE)
1	4.4735+1.1956*ln(T)	0.0245	0.0939
2	4.5239+1.1817*ln(T)	0.0217	0.0938
8	4.2111+1.2647*ln(T)	0.0191	0.0922
9	4.1248+1.2872*ln(T)	0.0188	0.0921
10	4.0323+1.3112*ln(T)	0.0219	0.0967
11	3.9596+1.3301*ln(T)	0.0223	0.1023

Table 1 shows that the last equation produced a greater error than the previous equation. This is the consideration that the most relevant linear regression equation is the equation produced by using data number nine as the starting data. Figure 3 shows the model, representing more than 98 percent of the data. So, the most relevant equation for this case is:

$$\ln(\text{MTBFc}) = 4.2111 + 1.2647 \cdot \ln(T) \tag{4}$$

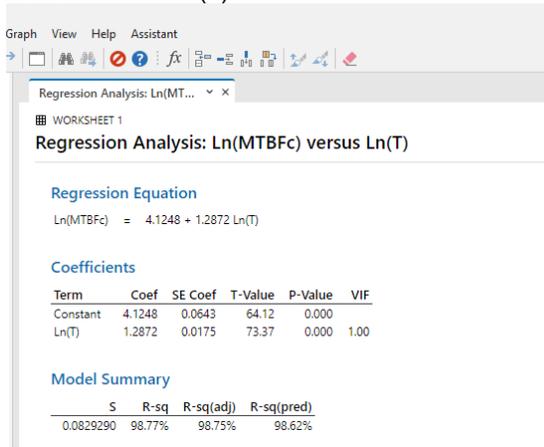


Figure 3. Regression Analysis by Minitab 19

The next step is compute the predicted value of MTBF for five periods, we said, data number 78 until 82. Using equation (4), we get the value for MTBF for periods 78 to 82, which are summarized in table 2.

Table 2.

Data number	Actual Value	Predicted Value	Difference/Error	MSE
78	261	270.9504	9.9504	99.01
79	276	278.7596	2.7596	7.61
80	285	279.7749	5.2251	27.30
81	299	280.7811	18.2189	331.92
82	278	281.7784	3.7784	14.27

Table 2 shows the predicted MTBF for the last five periods. In periods 78th, 79th, 82nd, there were negative differences; the predicted value of MTBF exceeds the actual one, respectively. So, we need to compute the MSE. The relative error is 9.8 hours, getting by averages the differences of last five periods.

4. CONVENTIONAL METHOD: MTBF DATA PATTERNS

In this method, the initial step taken is to identify the distribution of MTBF data. By using Minitab, the results are obtained; the pattern of the MTBF is 2-Parameter Exponential, as seen in Figure 4 and Figure 5.

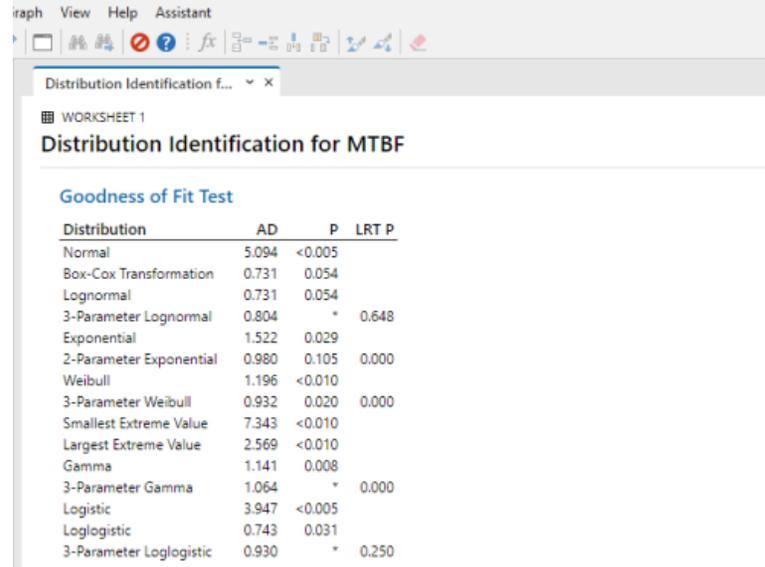


Figure 4. Distribution Identification for MTBF: 2-Parameter Exponential

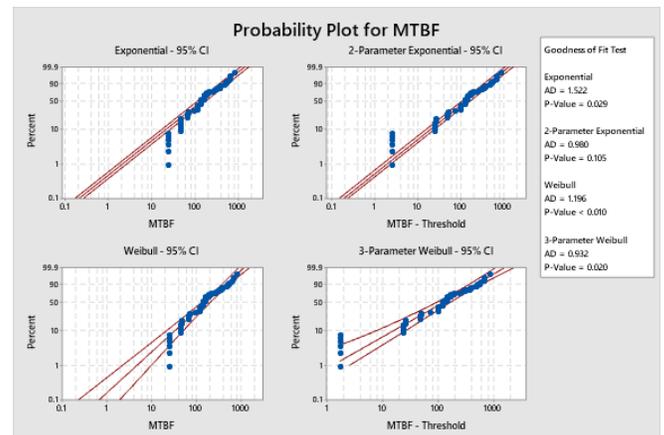


Figure 5. Probability Plot for MTBF

The 2-Parameter Exponential pdf is given by [6]:
 $f(t) = \lambda e^{-\lambda(t-\gamma)}, f(t) \geq 0, t \geq \gamma$ (5)
 where γ is the location parameter, scale parameter: is $\frac{1}{\lambda} = \bar{t} - \gamma = m - \gamma$. Using this formula, we get the result for the five periods, are 283.7591, 285.5471, 287.3351, 289.1231 and 290.9112. Table 3 shows the comparison between Duane Model and conventional method. About the

calculation results, we get a little different. The relative error of conventional method calculation is about 12.3 hours.

Table 3. *The Comparison between Duane Model and Conventional Method*

Period	Actual Value (hours)	Predicted value (hours)			
		Duane Model	MSE	Conventional Method	MSE
78	261	270.9504	99.01	283.7591	517.9747
79	276	278.7596	7.61	285.5471	91.1468
80	285	279.7749	27.30	287.3351	5.4527
81	299	280.7811	331.92	289.1231	97.5523
82	278	281.7784	14.27	290.9112	166.6983

5. CONCLUSION

In this case, the results of calculating the predicted MTBF in 2 ways, the Duane model and the conventional method, are compared. The relative error of the Duane model to the actual value is 9.8 hours. Meanwhile, conventional methods resulted 12.3 hours. It means that the Duane model is quite suitable to be used to determine MTBF, with a relatively small difference, 2.5 hours.

REFERENCES

- [1] Barlow, Richard E, and Frank Proschan. Mathematical Theory of Reliability. New York: John Wiley & Sons, Inc., 1965.
- [2] Carmines E, Zeller R (1979) Reliability and validity assessment. Sage Publications, Beverley Hills
- [3] Nelson, W., "An Application of Graphical Analysis of Repair Data," Quality and Reliability Engineering International, Vol. 14, pp. 49-52, 1998.
- [4] Wu, Shaomin and Zuo, M.J. (2010) Linear and Nonlinear Preventive Maintenance Models. IEEE Transactions on Reliability, 59 (1). pp. 242-249. ISSN 0018-9529.
- [5] Duane, J.T., "Learning Curve Approach To Reliability Monitoring," IEEE Transactions on Aerospace, Vol. 2, pp. 563-566, 1964.
- [6] Kececioglu, Dimitri, Reliability Engineering Handbook, Prentice Hall, Inc., Englewood Cliffs, New Jersey, Vol. 1, 1991.