Reliability and Life Data Analysis on the Components of Pump

Dewi Pitaloka[1*], Fachri Koeshardono[2]

[1]*Mechanical Engineering Department, Bandung State Polytechnic, Jl. Gegerkalong Hilir, Bandung 40559, Indonesia*
[2] *Mechanical Engineering Department, Bandung State Polytechnic, Jl. Gegerkalong Hilir, Bandung 40559, Indonesia*
**Corresponding author.Email: dewi.pitaloka.pmf16@polban.ac.id*

ABSTRACT
The aim of this study is to highlight the importance of analyzing the reliability and data analysis in the industry. This analysis makes it possible to determine the pattern of damage that has occurred in order to determine the right treatment strategy. This study was conducted in a state-owned company in the Oil and Gas sector. They suffer losses in the production process and high maintenance costs due to pump failure. This problem comes from the working fluid that is flowed containing a catalyst which is erosion-corrosion and affects the damage to the pump components. The pump is a type of centrifugal pump with the parallel installation. The identification of pump failures is completed in this analysis with the help of the existing asset criticality rating system and failure time data is collected from the last 15 years from 3 pump units to perform reliability and life data analysis. The analysis begins by determining the failure mode of each pump. The highest number of failures is associated with failure of the mechanical seal, and the bearings. The analysis was carried out using the aid of software to help determine the reliability and other parameters. After analyzing the reliability of the pump components, it is known that the pump components have failed differently. In mechanical seals, there is premature damage caused by the working fluid, and the bearings experience random failure. Based on the results of the reliability analysis that has been carried out, it is recommended to carry out predictive maintenance for a mechanical seal and bearing components and to make a maintenance schedule which is expected to extend the service life of the pump. The reason for the high maintenance costs is because the handling of the damage that occurs is not properly planned. The random failure mode is also one factor in increased maintenance costs.

Keywords: *Reliability, Availability, Erosion, Corrosion, Pump unit, Strategy Maintenance*

1. INTRODUCTION

Pumps are used in the industrial world to move fluids from one place to another with the principle of making a pressure difference between the inlet and the outlet. The pump that operates is designed to flow the working fluid containing a catalyst which causes the pump to break down quickly. A reliability study was conducted to determine the pattern of damage that occurred in order to determine the appropriate maintenance strategy in order to maintain the availability of the three pumps to keep functioning properly [8]. The analysis was carried out using the aid of software to help determine the reliability and other parameters. The parameters obtained are used to design a maintenance strategy in the form of a maintenance schedule.

1.1. Reliability

Reliability is a series of measurements or a series of measuring tools that have consistency in the extent to which the test can be trusted to produce a consistent score, relatively unchanging even though it is pressed in different situations [7,8].

1.2. Relationship between Availability, Reliability and Maintainability

Can be seen in the table below that although reliability is maintained constant even at high values, it cannot be concluded that the value of availability is also high, this is due to the decreased maintainability factor [7].

Copyright © 2020 The Authors. Published by Atlantis Press B.V.
This is an open access article distributed under the CC BY-NC 4.0 license -http://creativecommons.org/licenses/by-nc/4.0/.

Table 1 Relationship between Reliability, Maintainability and Availability

Reliability	Maintainability	Availability
Constant	Decreases	Decreases
Constant	Increases	Increases
Increases	Constant	Increases
Decreases	Constant	Decreases

1.3. Reliability Centered Maintenance (RCM)

Reliability Centered Maintenance (RCM) is a structured method for analyzing the function of potential failures with a focus on efficiently maintaining system functions with a certain level of operation and risk [6,7,8]

2. METHODOLOGY

2.1. Criticality Analysis

The first step to addressing this problem begins by collecting failure time data for the last 14 years from 2005-2019 and separating the various failure modes associated with this pump. The pump failure history is obtained from the pump failure history *card*.

The next step is to identify the criticality of the pump components. This is very important to do because applying the critical level of pump components it will focus only on equipment that is very critical and requires fast handling [4]. There are 3 pumps selected. The pump is a type of centrifugal pump with the parallel installation. Criticality Ranking is done with the help of the FMEA (Failure Mode Effect Analysis) table. It can be seen in the table below that the bearing and mechanical seal components have the highest RPN values.

Table 2 Failure Mode Effect Analysis

Failure Mode and Effect Analysis (FMEA)										Sheet of.........No....
System: Parallel Pump				Component: 15-P-102 A/B						
System Status:				Component Status:			Operating Condition:			Documentation:
tag Code	Failure Function	Failure Mode	Failure Effect	Cause of Failure	Process Control	Recommended Action	Severity (S)	Occurance (O)	Detection (D)	Risk Priority Number (RPN)
P 15-102 A/B	Casing	Crack Formation	Casing Perforated, gaps, pressure drop, erosion	The pressure is too high and the fluid is dirty	Adjustment of incoming fluid pressure, using the right fluid	Evaluate pressure rise and fluid content	4	6	3	(72)
P 15-102 A/B	Impeller	Deformation on Impeller	Cracked, perforated, unbalanced, high vibration impeller	Erosion and Contamination fluids	Using the right fluids and materials	Evacuate the chemical content in the fluid that is flowed	4	4	5	(80)
P 15-102 A/B	Shaft	Deformation on Shaft	Shaft scratched, size change and excessive vibration	Lack of lubrication	Proper use of lubricants	Prepare for preventive maintenance	7	4	3	(84)
P 15-102 A/B	Bearing	Defect Bearing	Excess vibration, eroded	Misalignment	Centering	Evaluate shaft and bearing position	6	7	3	(126)
P 15-102 A/B	Mechanical Seal	Leakage, Surface erosion, Crack	Fluid spills into the environment	Incorrect installation	Using a suitable seal, with an adjustable load	Study the troubleshoot book properly and apply it	9	8	2	(144)

2.2. Software Analysis

Easyfit testing was carried out on 3 installed pumps as well as on the bearing and mechanical seal components attached to the pump. In the first stage of testing carried out on pump damage, data sorting is carried out to obtain figures for how long (in days) the pump is replaced.

Figure 1 Table of damage that occurs to the pump based on the pump *failure history card*

Change the Pump	03/05/2017
Change Mechanical Seal and Bearing	04/04/2018
Change the Pump	14/09/2018
Change Mechanical Seal and Bearing	20/02/2019
Change Mechanical Seal and Bearing	26/02/2019

Here, the replacement of the pump occurs from 03/05/2017 to 14/09/2018, the duration of the damage that occurs if converted into days is 501 days. Then the data is into the table in the *software* as follows:

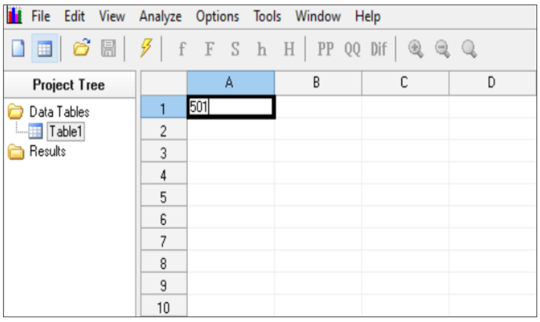


Figure 2 The initial table window in the *software* inputtedEasyfit.

After the data is collected, the data is analyzed further, namely adjustment into a distribution. Before that, it is necessary to select the type of data first, because the data being tested is pump damage data, so the type of data selected is discrete data.

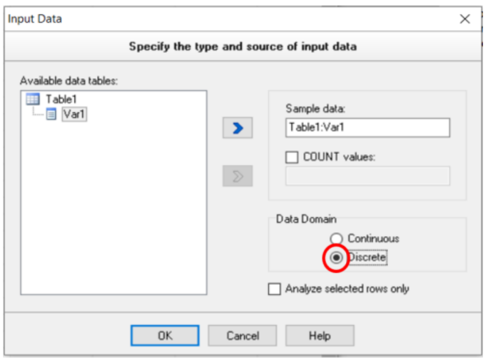
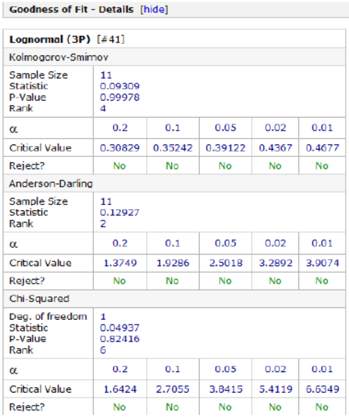


Figure 3 Data type selection window in the *software*

Determination of the most suitable distribution is done with the help of *software* in order to increase the certainty and the results obtained. With this tool, the authors can make adjustments to the data distribution into 55 models. The final model chosen is taken based on the best ranking and according to the recommendations of experts or existing theories for consideration. Based on the *software* EasyFit which functions as a power determination for each distribution, "lognormal 3 parameters" get the highest rank with the certainty score as follows:



Goodness of Fit - Details [hide]

Lognormal (3P) [#41]					
Kolmogorov-Smirnov					
Sample Size Statistic P-Value Rank	11 0.09309 0.99978 4				
α	0.2	0.1	0.05	0.02	0.01
Critical Value	0.30829	0.35242	0.39122	0.4367	0.4677
Reject?	No	No	No	No	No
Anderson-Darling					
Sample Size Statistic Rank	11 0.12927 2				
α	0.2	0.1	0.05	0.02	0.01
Critical Value	1.3749	1.9286	2.5018	3.2892	3.9074
Reject?	No	No	No	No	No
Chi-Squared					
Deg. of freedom Statistic P-Value Rank	1 0.04937 0.82416 6				
α	0.2	0.1	0.05	0.02	0.01
Critical Value	1.6424	2.7055	3.8415	5.4119	6.6349
Reject?	No	No	No	No	No

Figure 4 Lognormal 3 parameters

With the highest confidence value, which is 0.2 using the Kolmogrof-Smirnov theory, Anderson-Darling, Chi-squared, the initial hypothesis to reject the 3P lognormal distribution, failed to be rejected because the statistical value was smaller than the critical value [3]. These two values (value *statistical* and *critical value*) are obtained using the equation *Goodness of fit.* Based on the three methods *Goodness-of-fit, the* ranking of this distribution is very high compared to other distributions (55 distributions), besides that this distribution model is commonly used as a tool to analyze the data of *lifetime* a system [5].

After getting a conclusion about the distribution of the data, then the data above is analyzed with a 3p lognormal distribution [3]. The following is the result of the value of the three parameters:

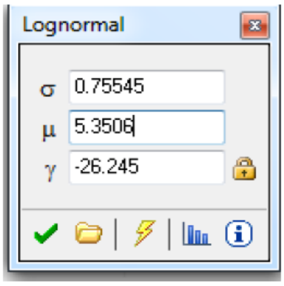
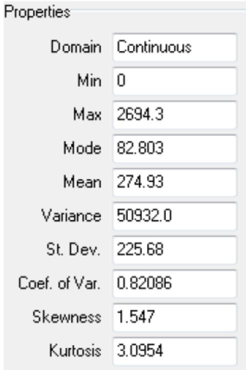


Figure 5 Data *Goodness of Fit*

There are 3 parameters, the first is σ which is the shape parameter, μ is the scale parameter, and γ is the location parameter. The values of the scale parameter and the location parameter μ have components of the *mean* and *standard deviation of the* normal data, so that the initial data normally distributed can be used as a lognormal model [3]. Location parameter γ of -26,245 or in other words it is identified that the initial damage has a datum of 26 days before the initial data is analyzed. After each parameter is obtained, the mean or value is obtained *Mean Time Between Failure* (MTBF). By using *software* EasyFit, all of the above data is processed and produces the *output* following:



Properties

Domain	Continuous
Min	0
Max	2694.3
Mode	82.803
Mean	274.93
Variance	50932.0
St. Dev.	225.68
Coef. of Var.	0.82086
Skewness	1.547
Kurtosis	3.0954

Figure 6 Data *Properties*

Based on the picture above the value *mean* shows that the *mean time between failure* in the system is 9 months, which means that the average pump change often occurs in months. 9th for this foundation. The value *standard deviation is* used to determine the upper and lower limits of the system. In addition, there are other parameters that can be analyzed, namely *skewness* and *kurtosis*, both of which can be analyzed based on the *Probability Density Function*, graph here is the graph [5]:

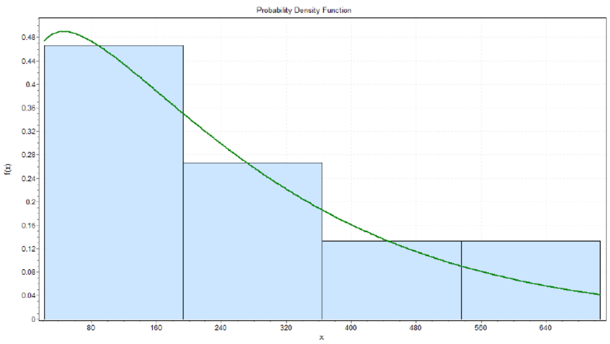


Figure 7 The graph of the *Probability Density Function*

Skewness obtained, informs that the tendency of this data is gathering towards the left, in accordance with The graph provided above, in other words, the possibility of the mean (x) data on the PDF graph of this foundation has decreased in fact, while the MTBF of this foundation has very little chance of increasing [3,5].

After getting the *Mean Time Between Failure value* by using *software* EasyFit, the reliability function is plotted automatically so that the analysis can be done more quickly. The reliability of this system after running is as follows:

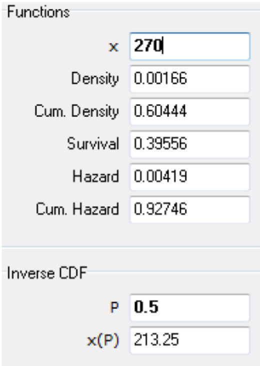


Figure 8 Reliability Data, Failure Probability, and *Hazard Rate*

Based on the data above, it is known that the value *cum. Density* shows the large value of the probability of failure experienced by the system, the value *survival* shows the value of the system reliability, *hazard* and *cum. Hazard* shows the value of failure experienced by the system [5]. The following is a graph of the *hazard rate* or *failure rate* of the system:

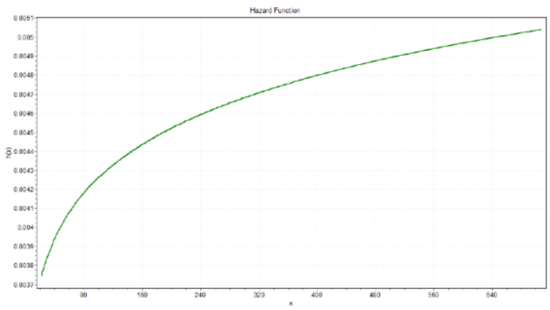


Figure 9 Graph of the function *hazard rate*

2.2. Total Software Analysis System

At this stage, it uses all the parameters that have been obtained from the calculation *of software* Easyfit [2]. In the *software* Raptor 4.0, we can add nodes and blocks as needed by right-clicking. The following options will appear:

Figure 10 Display the initial window of the *software The* Raptor

Patterns that are formed in *software* are adjusted to the conditions in the field. Each block is filled with all the parameters that have been obtained, here is an example of a block filling window from the *software* Raptor 4.0:

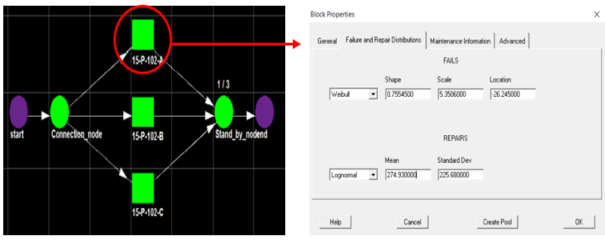


Figure 11 Display of the Data entry window for the process (block)

The left side shows the type of data distribution used, the selection of this distribution is adjusted to the results *of software* EasyFit. In the upper part, it is filled in accordance with the failure distribution of each foundation, while on the lower side, the filling is done with data *Mean Time to Repair* which results in the foundation having to remove the pump according to the agreement with the *workshop* [2,3,5].

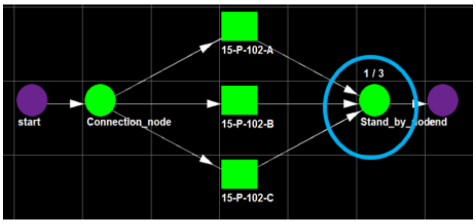


Figure 12 System Definition Display

Furthermore, the system is defined as a parallel system that requires at least 1 pump to drain the working fluid. This definition is done by setting node 1/3 which is after the process (block) of the three pumps.

After the data obtained from the *software is* EasyFit entered, the *software is* Raptor 4.0assigned to simulate this system, the following is a window display of the simulation that will be performed:

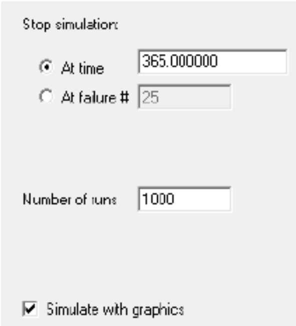
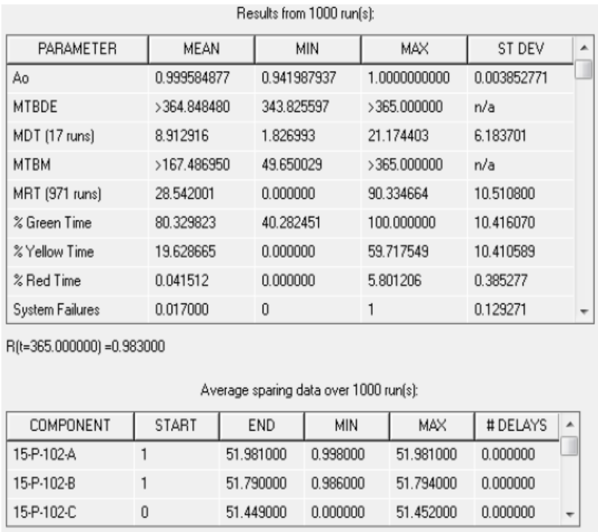


Figure 13 Data entry window for simulation

In the column *Stop simulation, At time,* the data to be filled in is a long time When the system is run in accordance with the time unit of the parameters used, if the parameter calculation is done in days, the filling in this column is in days, while the column *Number of runs* is the number of times the system is simulated with the same system condition for each simulation.

After the simulation is run, the *software* Raptor 4.0 will then display a window containing the results obtained, the following is a display of the results obtained:



Results from 1000 run(s):

PARAMETER	MEAN	MIN	MAX	ST DEV
Ao	0.999584877	0.941987937	1.0000000000	0.003852771
MTBDE	>364.848480	343.825597	>365.000000	n/a
MDT (17 runs)	8.912916	1.826993	21.174403	6.183701
MTBM	>167.486950	49.650029	>365.000000	n/a
MRT (971 runs)	28.542001	0.000000	90.334664	10.510800
% Green Time	80.329823	40.282451	100.000000	10.416070
% Yellow Time	19.628665	0.000000	59.717549	10.410589
% Red Time	0.041512	0.000000	5.801206	0.385277
System Failures	0.017000	0	1	0.129271

R(t=365.000000) =0.983000

Average sparing data over 1000 run(s):

COMPONENT	START	END	MIN	MAX	# DELAYS
15-P-102-A	1	51.981000	0.998000	51.981000	0.000000
15-P-102-B	1	51.790000	0.986000	51.794000	0.000000
15-P-102-C	0	51.449000	0.000000	51.452000	0.000000

Figure 14 Calculation Results *of the software* Raptor 4.0

3. CONCLUSION

Based on the results of the analysis carried out, the system reliability value can be influenced by several aspects. Based on the aspect *maintenance, reliability* can decrease if repairs are not carried out according to schedule and quality, besides the stock of pump components can cause repairs to be delayed [4]. Another aspect is age, if the repair results from the *workshop* do not provide good quality, then the life of the pump will decrease so that the pattern *maintenance* can be disrupted. Based on the results of the analysis *trend* of the graph *hazard rate, the* three pump foundations experienced an increase in the *hazard rate* throughout the day due to corrosion erosion. This cause cannot be avoided because it has become the working fluid characteristic of this system [1]. Meanwhile, *bearings* and *mechanical seals are* pump known to have problems in the design or installation process.

After analysis with software Raptor 4.0, the value *Availability* and *reliability of* the total system of 15-P-102 are equal to 99.9584877% and 98.3% with detail *availability* pump system to provide a third pump to be ready to operate at 80.329823%, one of the foundations does not functioning at 19.628665 %, after the system has been running for 1 full year with the limit of repairs made for each foundation is 30 days. It can be said that the system is good enough.

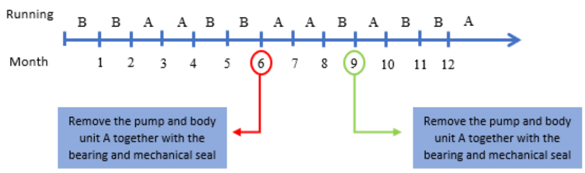


Figure 15 Strategy for A/B Pump Operation

Scheduling of pump operation is obtained based on the reliability value that has been obtained from the EasyFit analysis process [6]. For pump A, the maximum body change life is 9 months and the maximum bearing + mechanical seal life is 5 months. Whereas for pump B, the maximum body change age is 6 months and the maximum bearing + mechanical seal life is 4 months. Therefore, pump A will be repaired in month 6 and pump B will be repaired in month 9. This will make work more effective and save costs and time. The purpose of repairing the body along with repairing bearings and mechanical seals is to save costs and have the same replacement life so that you can prepare basis *spare parts* on a scheduled.

REFERENCES

[1] Gulati, R, & O Hanlon, T. (2013) Maintenance and reliability best practices. Newyork: Industrial Press.

[2] J Fraser, Warren H. *"Flow Recirculation In Centrifugal Pump".* Proceedings of The Tenth Turbomachinery Symposium.

[3] Aristizabal,Rodrigo J. *Estimating the Parameters of the Three-Parameter Lognormal Distribution* (2012), FIU Electronic Theses and Dissertations. 575

[4] T.Strawn,, T (2011, April 4). Maintenance Planning, Scheduling deliver to the bottom line.

[5] Meryam Krit. *Goodness-of-fit tests in reliability. Weibull distribution and imperfect maintenance models.*

General Mathematics [math.GM]. Universite de Grenoble, 2014. English NNT: 2014GRENM038. Tel-01126901.

[6] ReliaSoft Corporation., RS. (2015, May 22). Life_Data_Analysis_Reference_Book.

[7] Neil B.Bloom (2013). *Reliability Centered Maintenance.* New York McGraw-Hill.

[8] Kapur, K.C. and L.R. Lamberson, 2011, Reliability in Engineering Design, John Wiley, Newyork.