Reliability and Life Data Analysis on the Components of Pump

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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 unchanged 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].
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 1
| Reliability | Maintainability | Availability |
|-------------|-----------------|--------------|
| Constant    | Decreases       | Decreases    |
| Constant    | Increases       | Increases    |
| Increases   | Constant        | Increases    |
| Decreases   | Constant        | Decreases    |

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 | 04/06/2018 |
| Change the Pump | 14/09/2018 |
| Change Mechanical Seal and Bearing | 20/02/2019 |
| Change Mechanical Seal and Bearing | 24/02/2019 |

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:

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 \( \sigma \) which is the shape parameter, \( \mu \) is the scale parameter, and \( \gamma \) is the location parameter. The values of the scale parameter and the location parameter \( \mu \) 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 \( \gamma \) 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:

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](image)

**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](image)

**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](image)

**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](image)

**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](image)

**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 4.0 assigned to simulate this system, the following is a window display of the simulation that will be performed:
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:

**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.

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.

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