ASSESSMENT OF THE RELIABILITY OF THE IRT-T REACTOR'S CENTRIFUGAL PUMP

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1.0. Abstract

The purpose of this study is to emphasize how crucial it is to examine the industry's data analysis and reliability. With the help of this study, it is possible to identify the pattern of damage that has taken place and choose the best course of action. The D 320-50 centrifugal pump in the TPU's IRT-T reactor was used for this study. The primary goal of this research is to estimate the centrifugal pump dependability using recurrent data analysis for failure modes because the centrifugal pump that is the subject of this work has already had numerous significant failures. The reliability of each pump component can be calculated and evaluated for maintenance needs using the information from the daily operating report. To resolve the problem, however, a generic mathematical model and algorithms are needed because the data gathered from the location may be insufficient or incomplete.

2.0. Introduction

Plant production can be increased while operating costs are greatly decreased with proper equipment maintenance [1]. With the idea of producing a pressure difference between the intake and the exit, pumps are utilized in the industrial world to transport fluids from one location to another [2]. When designing the equipment or system for these pumps, performance criteria including dependability, availability, maintainability, and safety should be taken into consideration and maintained [3]. A total output loss and daily losses of more than a billion ringgit for the corporation are inevitable if the system fails frequently or for an extended period of time. To prevent this from happening, the system and its components need to undergo a dependability assessment. Reliability has elevated in importance over the past few years as a subject and element of organizational continuous improvement [4]. A prediction of the total dependability can be made using the component's time to failure. The system can also be divided into two categories: systems that can be repaired and those that cannot [5]. In this research the reliability of each pump component can be calculated and evaluated for maintenance needs using the information from the daily operating report. In this research D 320-50 centrifugal pump was chosen. The characteristics of this pump can be shown in the table 1 below. Weibull analysis will be used to calculate the reliability of each component.

Table 1. Characteristics of Centrifugal pump

Pump size	flow m^3/h	Head m	Power consumed by the pump (nom.), kW	Rotation frequency, rpm	Soviet equivalent since 1973	Voltage, V	Weight, kg
D320-50	320	50	60	1450	6NDV	380/660	326

3.0. Failure modes

The Ishikawa or Fishbone Diagram, a visualization tool for classifying the possible sources of a problem in order to find its root causes, was used to analyze the obtained data as part of the Root Cause Failure Reliability Centered Maintenance methodology. In troubleshooting sessions, a fishbone diagram is helpful to keep the dialogue on topic. The technique enables the researcher to draw conclusions from all potential explanations for a problem. The diagram's layout closely resembles a fish skeleton. The conventional way to draw a fishbone diagram is from right to left, with each big "bone" of the fish branching out to include smaller bones with more detail. The Fishbone method was used to look at the many causes or contributing factors that led to the failure of the pump as a whole. The causes can be seen in the fishbone diagram in figure 1 below [6, 7, 8].

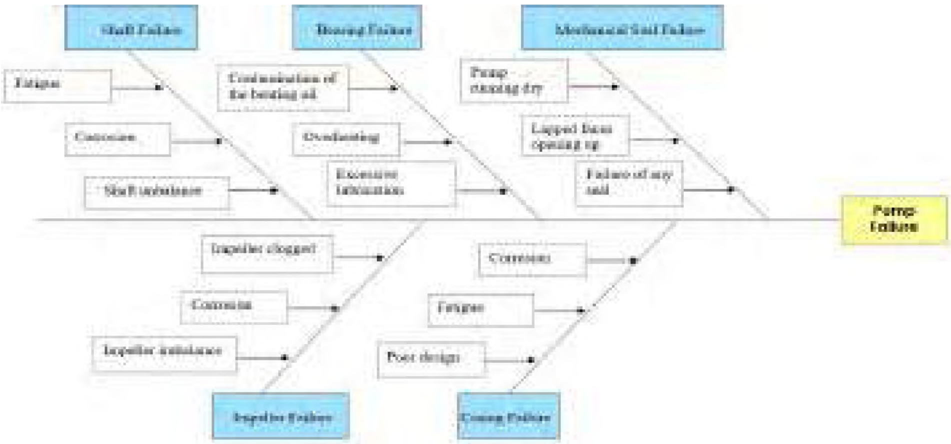

Fig. 1. Cause and Effect ("Fishbone") Diagram of Pump Failure

4.0. Preparing a mathematical model for calculation reliability

Weibull distribution

Weibull distribution is used in reliability engineering, medical research, quality control, finance, and climatology. Time-to-failure data, such as the probability that a part fails after one, two, or more years is required during the analysis. Weibull distribution is described by 3 parameters shape (β), scale (η(Eta)) and threshold parameters or location (γ). The probability distribution function can be used to derive reliability metrics such as the reliability function, failure rate, mean and median as shown in the equations below [9, 10].

Weibull reliability function can be determined by,

$$R(t) = e^{-\left(\frac{t-\gamma}{\eta}\right)^{\beta}}, \tag{1}$$

when threshold is zero equation 1 becomes,

$$R(t) = e^{-\left(\frac{t}{\eta}\right)^{\beta}}, \tag{2}$$

R(T) decreases for 0< β <1

For β =1, R(T) decreases monotonically but less sharply than for 0<ß<1

For β >1 R(T) decreases as increases

Weibull failure rate function can be calculated as shown in equation 3.

$$\lambda(t) = \frac{f(t)}{R(t)} = \frac{\beta}{\eta}\left(\left(\frac{t-\gamma}{\eta}\right)\right)^{\beta-1}. \tag{3}$$

Weibull mean life, or mean time to failure MTTF function can be determined by (4),

$$\overline{T} = \gamma + \eta \cdot \Gamma\left(\frac{1}{\beta} + 1\right), \tag{4}$$

where Γ is the gamma function

$$\Gamma(n) = \int_0^{\infty} e^{-x} x^{n-1}\, dx. \tag{5}$$

In order to find median ranks, Bernard's approximation is used (6).

$$F(t) = \frac{j-0.3}{n+0.4}, \tag{6}$$

where, j is the failure order while n is the sample size.

Serial and parallel connection of elements

In cases where the system consists of several parts, the failure of at least one of any of which results in the failure of the entire system is said to be serial connected. The block diagram of a series connection with K elements is shown in the figure 2 below [11].

The reliability of this system is expressed by (7),

$$R_s = P(E_1 E_2 E_3 \cdot \cdots E_k), \tag{7}$$

where: E_j is the successful operation (i.e., success event) of unit j, for j = 1, 2, 3, …, k; P ($E_1E_2E_3 \ldots E_k$) is the occurrence probability of events E_1, E_2, E_3, …, E_k; R_s is the series system reliability.

In cases where the system consists of several parts and the failure of only all parts results in the failure of the system, it is said that these parts are connected in parallel. The block diagram of a parallel connection with K elements is shown figure 3 below.

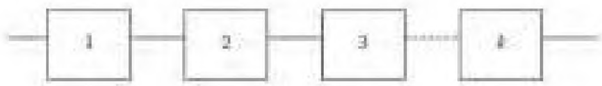

Fig. 2. A k-unit series system

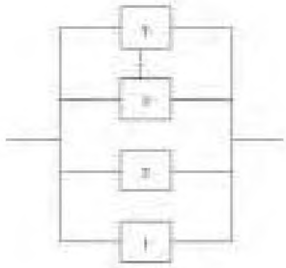

Fig. 3. Parallel connection of elements

Then,

$$F_P = F_1 F_2 F_3 \cdots F_K = \prod_{j=1}^{K} F_j, \tag{8}$$

where F_j is the unit j failure probability, for j = 1, 2, 3, …, k.

5.0. Calculation of reliability

The initial step in the analysis is to gather failure time data over a 5-year period and separate the many failure types connected with this pump. The pump failure history card is where you may find the history of pump failures. The next step is to determine which pump components are crucial. Applying the critical level of pump components will only concentrate attention on machinery that is extremely significant and needs quick handling. Therefore, doing this is crucial. Weibull distribution parameters were then calculated using analysis in Excel from the collected data. Different modes' failure times were arranged in ascending order. Bernard's approximation was then used to determine the median rank. Each failure's unreliability is calculated using the median rank. According to a 50 % confidence level and a sample size of N units, the median rank is the value that the true chance of failure should have at the j^{th} failure. Next, a probability plot of failure time against median rank was plotted.

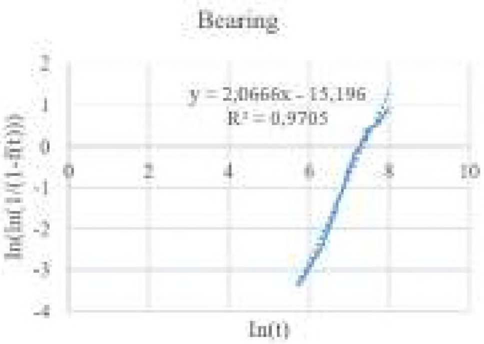

Fig. 4. Probability plot of failure time against median rank for the bearing

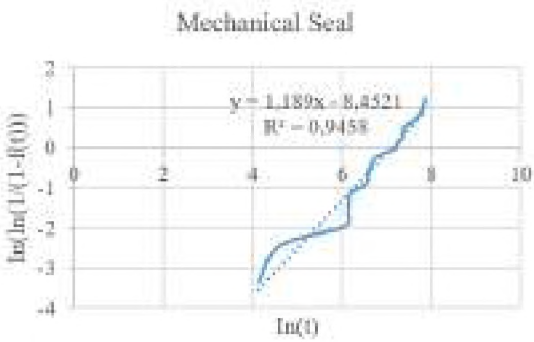

Fig. 5. Probability plot of failure time against median rank for mechanical seal

Component	Shape (β)	scale (η(Eta))	Reliability in 1year
Bearing	2,0666	1561,091	4,5712E-16
Mechanical Seal	1,189	1222,409	3,0503E-05
Impeller	1,6448	1147,377	5,0429E-13

The failure rates of the pump's casing, shaft, and motor were found in earlier studies. These components' reliability can be assessed based on their failure rates. The hourly failure rates for these parts are 2,6612E-7, 1,6216E-5, and 7,0584E-6, respectively [12, 13]. These components' annualized reliabilities are calculated to be 2,3285E-3, 0,1324, and 0,06 respectively. To calculate the overall reliability of the pump, the structural reliability scheme is drawn as shown below (7).

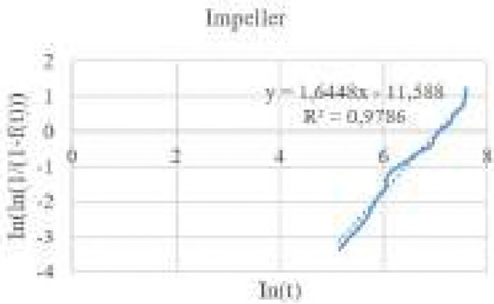

Fig. 6. Probability plot of failure time against median rank for impeller

Fig. 7. Structural reliability scheme of the pump

Considering that the pump elements are connected in series, then the overall reliability of the system can be calculated using equation 7.

R=4,5712E-16*3,0503E-5*5,0429E-13*2,3285E-3*0,1324*0,06=1,3007E-37.

6.0. Ways in which pump reliability can be improved

- To prevent infant mortality or early failure, review the routine maintenance procedures for all important equipment.
- Run-to-failure maintenance should replace time-based maintenance because time-based or predictive maintenance operations on random failure won't add value or lower the failure rate.
- In order to provide passive redundancy as part of a standby system, centrifugal pump units should be stacked in parallel (one pump is operating and the other is waiting in standby mode for the failure of the first pump).

7.0. Conclusion

To characterize centrifugal pump failure data and provide precise maintenance solutions, Weibull reliability analysis is appropriate. With the aid of this research, the management will be able to make the best choice for centrifugal pump availability and minimize plant downtime. An extra tool for performing maintenance to ensure the dependability of centrifugal pumps is provided by the availability indicators in the monthly report. The system reliability value can be modified by a number of factors depending on the findings of the analysis that was done. According to the maintenance aspect, reliability may suffer if repairs are not completed on time and with quality, and the availability of pump parts may delay repairs. Another factor is age; if the repair work done in the workshop is of poor quality, the pump's life may be shortened, and the maintenance schedule may be thrown off. Pumps are notorious for having issues during design or installation with bearings and mechanical seals. By using the Weibull analysis method, industries will be able to set priorities for centrifugal pump units based on their availability or how important they are to operations.

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АНАЛИЗ И ПЕРСПЕКТИВЫ СОВРЕМЕННЫХ ТЕХНОЛОГИЙ ДИАГНОСТИКИ ЧАСТИЧНЫХ РАЗРЯДОВ В ВЫСОКОВОЛЬТНОЙ ИЗОЛЯЦИИ

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Понятие частичного разряда в изоляции охватывает местный разряд на поверхности или внутри изоляции в виде короны, скользящий разряд или пробой отдельных элементов изоляции, шунтирующий часть изоляции между электродами, находящимися под разными потенциалами. Частичные разряды в изоляции возникают в местах с пониженной электрической прочностью (например, в прослойках пропитывающей жидкости или в газовых включениях в толще диэлектрик) [1].

Существует три основных метода диагностики ЧР:

- электрический;
- электромагнитный или дистанционно управляемый микроволновый метод;
- акустический; химический.

Электрический метод

Этот метод требует контакта измерительных приборов с изоляцией. Это позволяет определить большое количество характеристик частичного разряда. Это самый точный из всех методов измерения частичных разрядов.

Преимуществом метода является высокая чувствительность, но для поддержания надлежащей чувствительности необходимо устранить помехи или использовать фильтры. Электрические процедуры не опасны для изоляции оборудования, так как напряжение питания не сильно превышает номинальное.

Электрический метод измерения позволяет получить характеристики ЧР в режиме онлайн без задержек, которыми обладает хроматография. Существует также возможность при-