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Original Research Article

Reliability and Life Data Analysis on the Components of Pump

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Abstract: The purpose of this study is to highlight the importance of reliability and life data analysis in manufacturing facility which allows the maintenance and reliability professionals to analyse the equipment breakdown pattern and help decide the appropriate maintenance strategy. This study is conducted in one of the manufacturing plants based in Jubail, Saudi Arabia. They experienced production loss and high maintenance cost due to pump failure. The existing maintenance strategy is preventive maintenance (time based maintenance) and the plant experienced failure even after performing the routine maintenance activities. The challenge here is to investigate why the components of pump are failing after performing maintenance activities and to find the reason for high maintenance cost. A set of critical pumps are identified which have failed multiple times during past six years from the list of many operational pumps. The identification of pumps is completed with the help of existing asset criticality ranking system and the time to failure data is collected from the past six years to perform the reliability and life data analysis. The analysis started by determining the failure modes of each pump .The highest number of failures are attributed to the failure of pump seals, bearings, and impellers. The Weibull analysis helps to determine the reliability and its parameters (beta and eta). The shape parameter beta is represents the failure rate behaviour i.e. if beta is < 1, failure rate decreases with time, if beta is equal to 1, failure rate is constant, and it beta is > 1, failure rate increase with time and the eta is the scale parameter. After performing the reliability and life data analysis on the component of a pumps, it's found that the pump components have different failure pattern i.e. seals and bearing are having infant mortality or early failure whereas impeller is having random failure. Based on this outcome of reliability & life data analysis, recommended maintenance task for seals and bearing is predictive maintenance techniques such as maintenance procedure enhancement, developing the knowledge and skill set of maintenance crew etc. and for impeller is run to failure. The reason for high maintenance cost is due to the fact the unplanned maintenance cost is usually 30% higher than the planned maintenance cost and also the maintenance crew was preforming time based actions on random failure mode which is not adding any value but increases the maintenance cost.
Keywords: Weibull analysis, replaceable systems, reliability analysis, criticality analysis

INTRODUCTION

The reliability study is carried out for a set of pumps used in a one of the manufacturing facility in Jubail, Saudi Arabia. Pumps are failing unexpectedly causing a downtime and high maintenance cost. The current maintenance strategy for these pumps is preventive maintenance (time-based maintenance). Due to unexpected failures, maintenance crew was repeatedly performing corrective actions apart from the routine preventive maintenance to restore the pumps back to operations. These unplanned maintenance actions are causing a significant increase in maintenance cost.

A study says that the cost of unplanned maintenance activities is 30% higher than planned maintenance activities [10].

This case is selected for reliability study to find out the reason of unexpected failures and to decide applicable maintenance strategy with a right frequency.

CRITICALITY ANALYSIS

The first step to cater this problem begins with identifying the criticality of these pumps. It's very important to identify the asset criticality before you start applying reliability analysis because only 10% or 20% of plant equipment are causing 80% or 90% of problems. So, the focused should be only on these critical equipment rather than others [2].

A total of 4 identical critical seawater pumps are selected from the list of critical pumps to perform reliability and life data analysis, organization's asset criticality ranking system utilized to identify the critical pumps [1,2]. The next bid was to start collecting the time to failure data, associated maintenance cost for a period of last 6 years and segregate the various failure modes associated to this pump [2,7]. Failure history of this pump is obtained from organization's CMMS system to perform the Weibull analysis which is used to provide the indication of equipment failure pattern and helps determine the equipment reliability at a given time [1]. The main components of the pumps which are studied in this study are impeller, seals and bearings.

Table-1: Critical high lift seawater pumps

PUMP NAME	DESCRIPTION	TYPE	FAILURES #
Pump-1	High Lift Pump	Seawater Pump	5
Pump-2	High Lift Pump	Seawater Pump	3
Pump-3	High Lift Pump	Seawater Pump	6
Pump-4	High Lift Pump	Seawater Pump	5

IDENTIFICATION OF FAILURE MODES

The highest number of failures is attributed to the failure of pump components mechanical seals followed by impeller, and bearings. Mechanical seals and bearings are essentially non-repairable items and are currently being replaced upon failure [2,6,8]. It is found that a total of 19 failures had happened on 4 identical high lift seawater pump over past 6 years and the majority (80%) of pump failures is because of impellers, seals and bearings [2].

- The highest failures i.e. 38% are with Mechanical seal from the total number of failures.
- The second highest failures i.e. 26% are with impellers
- And the third highest failures i.e. 16% are with bearings.

LIFE DATA ANALYSIS / WEIBULL ANALYSIS

Now, it's time to determine the failure patterns of each component of this pump. The ReliaSoft Weibull++ software is used for reliability and life data analysis [1,3,4]. The name Weibull came from its inventor, Waloddi Weibull, and this distribution is widely used in reliability and life data analysis due to its versatility and simplicity [1,3,4]. The most general expression of Weibull is given by three parameters beta, eta and Gama where beta is the shape parameter also known as Weibull slope, eta is the scale parameter and Gama is the location parameter [1,3,4]. Frequently the location parameter is not used and the value of this parameter is set to zero. The pdf equation reduces to two parameter Weibull distribution [1,3,4].

The important characteristics of the Weibull distribution are beta and eta [1]. These parametric values helps in understanding the failure pattern i.e. whether the failure is on infant mortality or random failures or wear out., reliability of the component at given time etc. [1,3,4]

- Weibull distribution with beta < 1 have failure rate that decrease with time, also known as infant mortality or early life failures [1,3]
- Weibull distribution with beta close or equal to 1 have constant failure rate, also known as useful life or random failures [1,4].
- Weibull distribution with Beta > 1 have a failure rate that increase with time, also known as wear-our or age related failures [1,4].

These comprise the three sections of the "bathtub curve" as shown below [1,3,4].

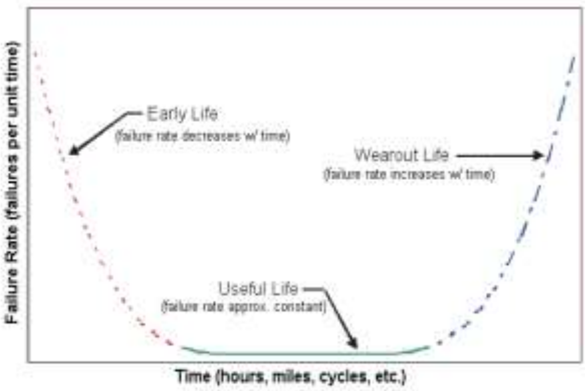

Fig-1: Bathtub Curve

THE WEIBULL ANALYSIS FOR REPAIRABLE AND NON-REPAIRABLE SYSTEMS

The time to failure data which was collected over 6 years from a CMMS system was analysed and its related reliability parameters i.e. Beta and Eta were determined [1-4].

The non-repairable component of this pump is found to be seal and bearings and the repairable component are found to be impeller. The maintenance crew was following the replacement strategy when seals or bearings failed [2,6].

TIME TO FAILURE DATA FOR MECHANICAL SEAL FAILURE

The time to failure data of mechanical seal is analysed in Weibull++ software to find the shape parameter and characteristics of life. Below is the time to failure data obtained from historian "CMMS".

Table-2: Time to failure data for mechanical seal failure

S.NO	TIME TO FAILURE (hr)	FAILURE MODE
1	1372	Mechanical Seal
2	2370	Mechanical Seal
3	496	Mechanical Seal
4	101	Mechanical Seal
5	1630	Mechanical Seal
6	770	Mechanical Seal
7	62	Mechanical Seal

The shape parameter for mechanical seal is lesser than one i.e. 0.78 which is considered as infant mortality or early failure and the characteristic life of mechanical seal is 1.39 months which is 0.11 years. [1-3]

Probability Weibull Plot – time (hr) Vs unreliability is shown below.

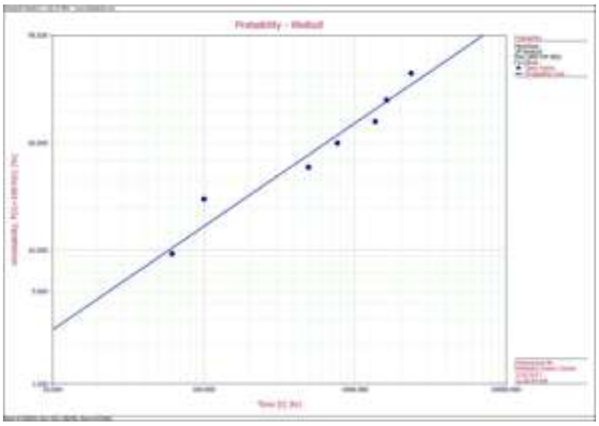

Fig-2: Weibull Plot for mechanical seal failure

TIME TO FAILURE DATA FOR BEARING

Time to failure data for Bearing is also analysed in Weibull++ software to find the shape parameter and characteristics of life. Below is the time to failure data obtained from historian "CMMS".

Table-3: Time to failure data for bearing failure

S.NO	TIME TO FAILURE (hr)	FAILURE MODE
1	1695	Bearing
2	4213	Bearing
3	311	Bearing

The shape parameter for bearing is lesser than one i.e. 0.73 which is considered as infant mortality or early failure and the characteristic life of bearing is 3.34 months which is 0.27 years [1-3].

Probability Weibull Plot – time (hr) Vs unreliability is shown below.

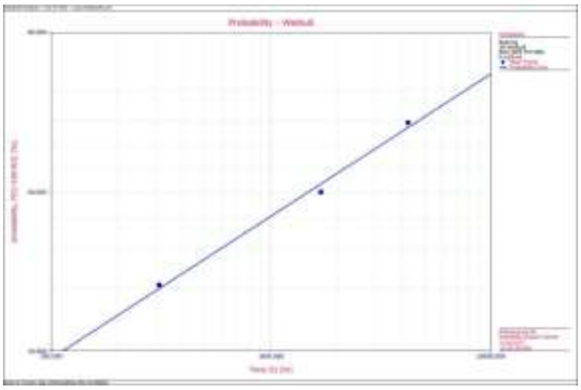

Fig- 1 Weibull plot for bearing failure

TIME TO FAILURE DATA FOR IMPELLER

Time to failure data for Impeller is also analysed in Weibull++ software to find the shape parameter and characteristics of life. Below is the time to failure data obtained from historian "CMMS".

Table-4: Time to failure data for impeller failure

S.NO	TIME TO FAILURE (hr)	FAILURE MODE
1	1276	Impeller
2	1942	Impeller
3	583	Impeller
4	172	Impeller
5	1456	Impeller

The shape parameter for impeller is slightly greater than one and shall be considered as equal to one i.e. 1.09 which is considered as Random failure and the characteristic life of impeller is 1.75 months which is 0.14 years [1,2,4].

Probability Weibull Plot – time (hr) Vs unreliability is shown below.

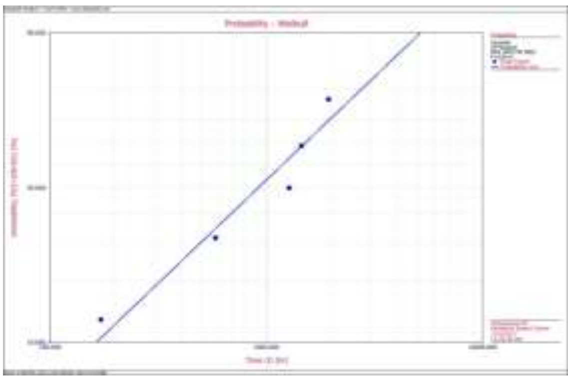

Fig-4: Weibull Plot for impeller failure

The Beta and Eta parameters plays an important role in determining the failure patters and help decide the maintenance strategy[1-4]. With the help of Weibull Analysis, we can now formulate the best applicable maintenance strategy to prevent the component of pump failure in this fashion. Also, by using probabilistic Weibull plot, it's possible to predict the failure time of the pump and to plan a particular action to minimize the risk of pump failure [1].

It's now possible to conclude that the major failures of pumps associated to components i.e. seals, bearings, and impeller has a failure pattern of infant mortality or early failures and random or useful life [1,9].

The applicable maintenance strategy for infant mortality is PDM (predictive maintenance) techniques such as effective maintenance procedure development, improving the knowledge and skills of maintenance crew etc. and for random failures, the applicable maintenance strategy is PDM (predictive maintenance), or RTF (run to fail), or re-design [1,2,9].

Upon further investigation,

- It's found that seals and bearings were failed due to wrong installation. Maintenance crew was not fully aware of SMP (standard maintenance procedure) and it's not written as a form of instructions [1,2,7,9].
- For impeller failure, a set of time-based maintenance actions was done to prevent the failures but they still continue experienced the unexpected failures [1,2,7,9].

RECOMMENDATIONS

After carrying out the Weibull Analysis and further investigation, the following recommendations are proposed:

For seals and bearings failure:

- o Review the standard maintenance procedures for all critical equipment to avoid infant-mortality or early failures.
- o Improve the knowledge and skill sets of maintenance crew by providing effective training.

- For Impeller failure:
  - o Replace the time-based maintenance strategy with Run-to-failure because performing time-based or predictive maintenance actions on random failure will not add any value and it will not reduce the failure rate. If you're performing time-based or predictive maintenance actions on random failure, you will have planned maintenance cost and un-planned maintenance cost because failure will happen.

CONCLUSION

The Reliability and Life Data Analysis (Weibull Analysis) using Weibull++ software found to be very beneficial to find out the component failure patterns and to design appropriate maintenance strategy. With the help of this analysis, maintenance strategies development department will be able to deploy the right maintenance strategy for the right equipment at the right time to minimize any unscheduled upset and downtime.

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