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Availability of Centrifugal Pump on the Basis of Weibull Analysis

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Abstract: ***The purpose of this paper is to focused on availability of centrifugal pump with the help of weibull analysis. Weibull analysis help to maintenance managers to capable for taking the right decision to require improvements in centrifugal pump for its availability.***

Keywords: Centrifugal pump, reliability, weibull analysis and availability.

1. Introduction

The Weibull analysis is that technique in which statistical data is analyze. This type of analysis permits to determine the failure behavior of the mechanical seal, bearings, shaft and impeller. The Weibull distribution is frequently used for its great variety of shapes that able to many types of data, especially data relating to component life. [1]

Weibull analysis includes following features: [2]
1. Forecasting and prediction of failure data.
2. Maintenance planning and cost effective replacement strategies.
3. Calibration of complex design system i.e. CAD/CAM, finite analysis… etc.
4. Evaluating corrective action plan.
5. Spare parts forecasting.

The Weibull frequency distribution or probability density function has two parameters:
1. Shape Parameter (β) – it defines the shape of the distribution.
2. Scale Parameter (η) – it defines the spread of the distribution.

2. Two Parameter Weibull distribution and its Characteristics

Weibull distributions come in two and three-parameter variants. A third parameter can be successfully used to describe failure behavior when there is a time period where no failure CAN occur (e.g. ball bearing failures due to wear). In most other cases, a two parameter description is preferable.[3]

$$\lambda(t) = \frac{\beta}{\eta}\left(\frac{t}{\eta}\right)^{\beta-1}$$

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

Where:
R(t): Reliability value
λ(t): Failure rate

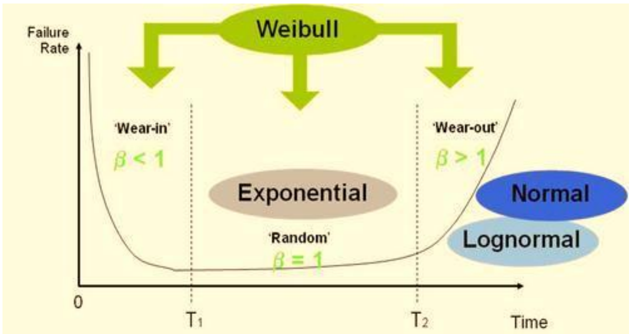

Figure 1: The Weibull distribution models each region. Beta is the shape parameter [4]

F(t) defines the fraction failing or probability of failing before time *t* (or unreliability at time *t*) and has an explicit equation [5]

$$F(t) = 1 - e^{-(t/\eta)^{\beta}}$$

The reliability function or probability of survival at time *t* is given by [5]

$$R(t) = e^{-(t/\eta)^{\beta}}$$

The general relationship between η and MTTF is given by the following equation [5]

$$MTTF = E(T) = \mu = \eta\Gamma\left[1 + \frac{1}{\beta}\right]$$

Where Γ(•) is the gamma function.

The following are some statistical characteristics that should be calculated during a typical Weibull analysis procedure being applied to analyze the machinery time to failure data [6]

Variance

$$\sigma^2 = \eta^2\left[\Gamma\left(1+\frac{2}{\beta}\right) - \Gamma^2\left(1+\frac{1}{\beta}\right)\right]$$

Mode

$$T_m = \eta\left[\frac{\beta-1}{\beta}\right]^{\frac{1}{\beta}}$$

Co-efficient of Variation

$$K = \frac{\sigma}{\mu} = \frac{\sqrt{\Gamma\left(1+\frac{2}{\beta}\right) - \Gamma^2\left(1+\frac{1}{\beta}\right)}}{\Gamma\left(1+\frac{1}{\beta}\right)}$$

Quantile t_p is given by

$$t_p = \eta\left(\ln\frac{1}{1-p}\right)^{1/\beta}$$

where $F(t_p)=p$.

Median $T_{0.5}$

$$T_{0.5} = \eta(\ln 2)^{1/\beta}.$$

3. Failure Data of Centrifugal Pump

Table 1: Critical Centrifugal Pump [Source: Reputed Manufacturing Industry]

Pump No.	Unit Location of Pump	Function	No. of Failures in 3 years
P1	Filtration Unit	Distillate Pump	6
P2	RCC Unit	Domestic water supply	7
P3	Vapour Pressure Impregnation Unit	Brine impregnation	5
P4	Manufacturing Unit	Furnace cooling	6
P5	Jal Pradaye Sanyantra Unit	Unusual water collection	4

Failure Modes of Centrifugal Pump: [7]

Type of Failures	Symptoms
Functional Failure	No liquid delivered
	Not enough liquid delivered
	Pump works for a while then quits.
	Pump takes too much power.
	Pump loses prime after starting.
	Viscosity of liquid differs from design condition.

Type of Failures	Symptoms
Potential Failure	Bearing Failure
	Seal Leakage
	Shaft Cracks
	Pitting marks on impeller
	Misalignment

Table 2 Reliability Parameters for Centrifugal Pump

Pump No.	β	η (months)	MTBF (months)	Standard Deviation (months)	Coefficient of Variance	Mode, Tm (months)	T0.5 (months)
P1	1.19	10.28	9.70	8.20	0.84	2.21	7.55
P2	2.09	6.60	5.80	2.90	0.50	4.84	5.54
P3	1.11	6.98	6.70	6.00	0.90	0.89	5.02
P4	1.26	8.70	8.10	6.50	0.80	2.49	6.50
P5	1.15	7.09	6.70	5.90	0.87	1.21	5.16

Table 3: Availability of Centrifugal Pump at Various Units

Pump No.	β	η (months)	MTBF (months)	MTTR (months)	Availability (%)
P1	1.19	10.28	9.70	0.82	92.21
P2	2.09	6.60	5.80	0.56	91.20
P3	1.11	6.98	6.70	0.73	90.18
P4	1.26	8.70	8.10	0.79	91.11
P5	1.15	7.09	6.70	0.73	90.18

Where,
MTBF = Mean Time Between Failures
MTTR = Mean Time To Repair
MTBM = Mean Time Between Maintenance action
M = Maintenance Mean Downtime (including preventive and planned corrective downtime)

Availability = MTTR / (MTTR + MTBF)

Inherent Availability: consider only corrective downtime.

Inherent Availability = MTBF / (MTBF + MTTR)

Achieved Availability: consider both preventive maintenance and corrective maintenance.

Achieved Availability = MTBM / (MTBM + M)

Operational Availability: ratio of the system uptime and the total time.

Operational Availability = Up Time / Operation Time

Achieved Availability↑ = MTBM↑/ (MTBM+M↓)

Where
M = Maintenance Mean Downtime (including preventive and planned corrective downtime
On the basis availability, the pump unit order in descending order:
1. P1 = Filtration Unit.
2. P2 = RCC Unit.
3. P3 = Vapor Pressure Impregnation Unit.
4. P4 = Manufacturing unit.
5. P5 = Jal Pradaye Sanyantra Unit.

4. To Improve Availability

1. Improve MTBM:
- Decreses Preventive Programs to a less, or, have Preventive intervals as well defined as require.
- Applying Predictive startegies whenever possible
- Implementing Maintenance Engineering (FMECA, RCM...)

2. Reduce Maintenance Mean Downtime (M):
- Implementation of Maintenance Engineering (Planning, Logistics...)
- Enhance personnel technical skills (training)
- Prepared a Integrated Planning (Maintenance+Inspection+...)

5. Results and Discussions

1. Reduces fully developed scheduled maintenance tasks by between 40-70%
2. Reduces disposal fees of material by between 30-50%.
3. Reduces the total number of maintenance man-hours expended by 35-60%.
4. Improved operating performance.
5. Cost effective maintenance.
6. Greater environmental and safety integrity
7. It provides a comprehensive database, greater motivation among participants, and better teamwork.

6. Conclusions

1. Weibull reliability analysis is suitable to characterize the centrifugal pump failure data and provide the exact maintenance strategies.
2. With the help of this analysis, management will be able to take the right decision for availability of centrifugal pump and reduces downtime of plant.
3. Availability indicators in the monthly report provide an additional tool for implementation of maintenance for reliability of centrifugal pump.
4. Prioritize the centrifugal pump units based on availability or criticality to operation. Assign components into logical groupings.

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