RELIABILITY BASED MAINTENANCE PLANNING OF A HIGH PRESSURE PUMP USED IN A DETERGENT PLANT

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Abstract : Continuous generation of detergent of a detergent production plant depends on the higher reliability of its components/equipments. The components/equipments however well designed will not perform without proper maintenance. Therefore maintenance is an important activity for improving reliability of the plant as well as its productivity. The high pressure pump (HP Pump) of a detergent production plant is an important subsystem as its failure leads to the stopping of the detergent production.

This paper has investigated the reliability characteristics of a HP Pump used in a detergent production plant in eastern region of India and scheduled the preventive maintenance based on reliability.

Keywords: Reliability, Increasing Failure Rate, Preventive Maintenance Scheduling, Failure Modes and Effects Analysis.

1. Introduction

With the rapid growth in FMCG market in India detergent consumption is increasing with leaps and bounce. One of the most important requirements of any detergent production plant is to guarantee its higher availability for maximization of production. The higher availability of a complex detergent production plant depends on higher reliability and maintainability of its components/ equipments.

The components/equipments of a detergent plant, however well designed, will not perform satisfactorily unless they are well maintained. Hence the general objective of maintenance of the equipments is to make use of the relevant information regarding failures and repairs.

Woo (1980) studied the reliability of an experimental fluidized-bed boiler of a coal-fueled plant to determine the major contributors to plant outage in terms of equipment failure and plant management. Arora and Kumar (1993) planned maintenance of coal crushing system in the coal-fired thermal power plant. Kaushik and Singh (1994) analyzed reliability of the feed water system in a thermal power plant. They calculated reliability and availability function (A_v) and mean times to failure (MTTF) of this system, followed by analysis of the results. Arora et al. (1995) analyzed reliability and of coal conveyor system in a thermal power plant and planned its maintenance program. They derived the expressions for steady state availability and the MTBF (mean time between failure), considering constant failure and repair rates for each working unit. Rahman et al. (2010) worked on root cause failure analysis of a division wall superheater tube (super alloy Inconel® 800) of a coal-fired power station. Purbolaksono et al. (2010) had undergone failure case studies of SA213-T22 steel tubes of the reheater and superheater of boiler. Therefore it is imperative to investigate the RAM characteristics of all mechanical equipments, for taking necessary measures regarding maximization of detergent production. J. Barabady (2005) has suggested that the setting of Preventive Maintenance Intervals (PMI) of mining equipments initially at 75% reliability level excluding maintenance cost. Adhikary et. al. (2010) presented the reliability based maintenance strategy of a coal-fired power plant.

In this research work an investigation is done on the reliability characteristics of the High Pressure Pump (HP Pump), a series system, used in a detergent manufacturing plant. Then the Preventive Maintenance Interval of the HPP has estimated at 75%, 80% & 90% reliability levels for performing their PM.

2. Data collection

The three years failure data of the HPP have collected from the plant's maintenance logbook records.

3. Description of the Detergent Production Plant

The functional block diagram of the detergent production plant is shown in the Fig.1. Several compositions of detergent powder are mixed in the Clutcher/Reactor. Then the mixture is stored in a large vessel for 2-3 hrs for aging. For achieving perfect mixture, Reitz mill is incorporated. H.P pump takes this mixture and after compressing it to about 45 kg/cm2 pressure sprays it to the cooling tower by Nozzles. It is then transferred in Base powder silo storage tank. Next mixing of perfumes and other ingredients are done and then it is delivered to the Boon mixer. Through three leg hopper it is finally conveyed to the Packing Section.

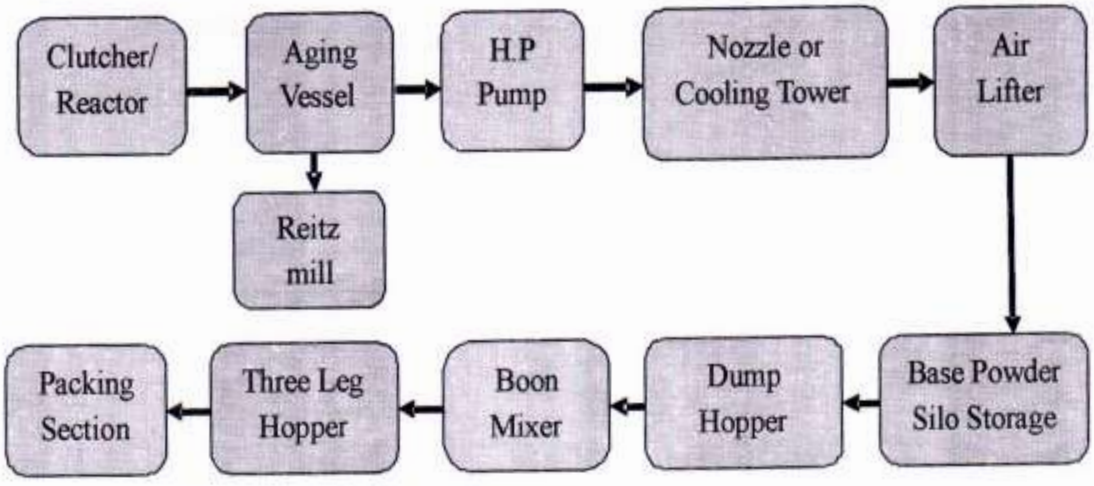

Fig.1. Functional block diagram of the detergent production plant

The pump can be considered as the series system of the plant as its failure leads to the stopping of the detergent production. Therefore its reliability analysis is very important for proper maintenance scheduling.

The pump specification is shown in the Table 1. The components and their functions are also described in the Table 2

Table 1. Pump specification

Parameters	Specifications
Type:	Plunger type Reciprocating Pump
Suction Pr.:	1-6 kg/cm^2
Discharge Pr.:	45-50 kg/ cm^2
Power:	45-50 kg/ cm^2
R.P.M:	1400

Table 2. Components and their functions

Sl No.	Components	Function
1	Cylinders	Compresses the slurry
2	Plungers	Act as pistons
3	Seals	Provide sealing at junctions
4	Glands	Provide the junction
5	NRV Block	Contains the Cylinders
6	Carbon Ring	Provide internal sealing between Plunger and Cylinder wall
7	Lub oil	Lubricate the moving parts
8	Water pipeline	Provide cooling effect
9	Oil Strainer	Purify the lub oil
10	V Belt	Power Transmission

4. Weibull parameters estimation

Reliability is the probability of a system or a component to perform its required function under stated condition for a specified period of time.

Various distributions are used to fit with the time between failures (TBF) data. In this research work the Weibull distribution is considered for the TBF data as it is very flexible and most commonly used model in failure data analysis (Ghodrati 2005).

The reliability of the Pump can be calculated (Ebeling, 2008) as:

$$R(t) = e^{-\left(\frac{t}{\theta}\right)^{\beta}} = \exp[-\{(t/\theta)^\wedge\beta\}]$$

where, â is Shape parameter & è is Scale parameter

The parameters for the best fitted statistical distributions are estimated by least-square curve fitting method (Adhikary et al. 2012). In the Weibull model, the parameters â (Shape parameter) and è (Scale parameter) can be determined by plotting lnln[1/{1-F(t_i)}] along y-axis against ln(t_i) along x-axis. The slope and intercept of the least-square fitted straight line to these data pints are the value of â and âlnè respectively (Ebeling, 2008). Equation of the least-square fitted straight line to the above data points in the plot is given as (Ebeling, 2008):

$$\mathrm{In\,In}\left[\frac{1}{1-F(t_1)}\right] = \beta\mathrm{In}\,t - \beta\mathrm{In}\,\theta$$

where F(t_i) = (i-0.3)/(n+0.4) = cumulative percentage of failures or repairs and t_i is ith TBF

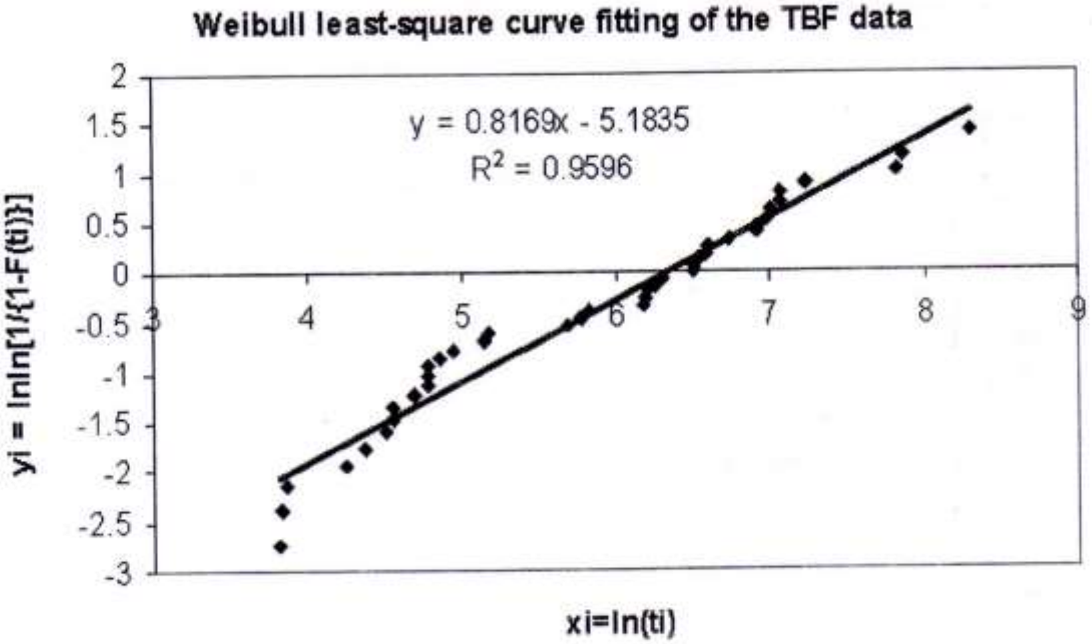

Fig. 2. Least-square fitted plot for data points (x_i=*ln(t)*, y_i=*lnln[1/{1-F(t)}]*) of the HP Pump In the plot, Intercept = *âlnè* = -5.183 and Slope = â =1.3032, therefore è=2813

5. Reliability Estimation

For the Weibull distribution of the operation times, the reliability and corresponding MTTF can be calculated as:

$$R(t) = \exp\left[-\int_0^t \lambda dt'\right] = \exp\left[-\int_0^t \frac{\beta}{\theta}\left(\frac{t'}{\theta}\right)^{\beta-1} dt'\right] = e^{-(t/\theta)^{\beta}}$$

Reliability of the HPP at various operation times is shown in the Table 3 below.

Table 3. Reliability of the HPP at various operation times

Operation Time	Reliability
0	1
100	0.900724745
179	0.800217027
200	0.773023364
257	0.700007116
300	0.646540921
400	0.530515331
500	0.42859479
600	0.341690332
700	0.269247781
800	0.209955284
900	0.162167665
1000	0.124163276
1500	0.029188107
2000	0.005876916
2500	0.00104321

The reliability of the HPP at various operation times is illustrated in figure 3 below.

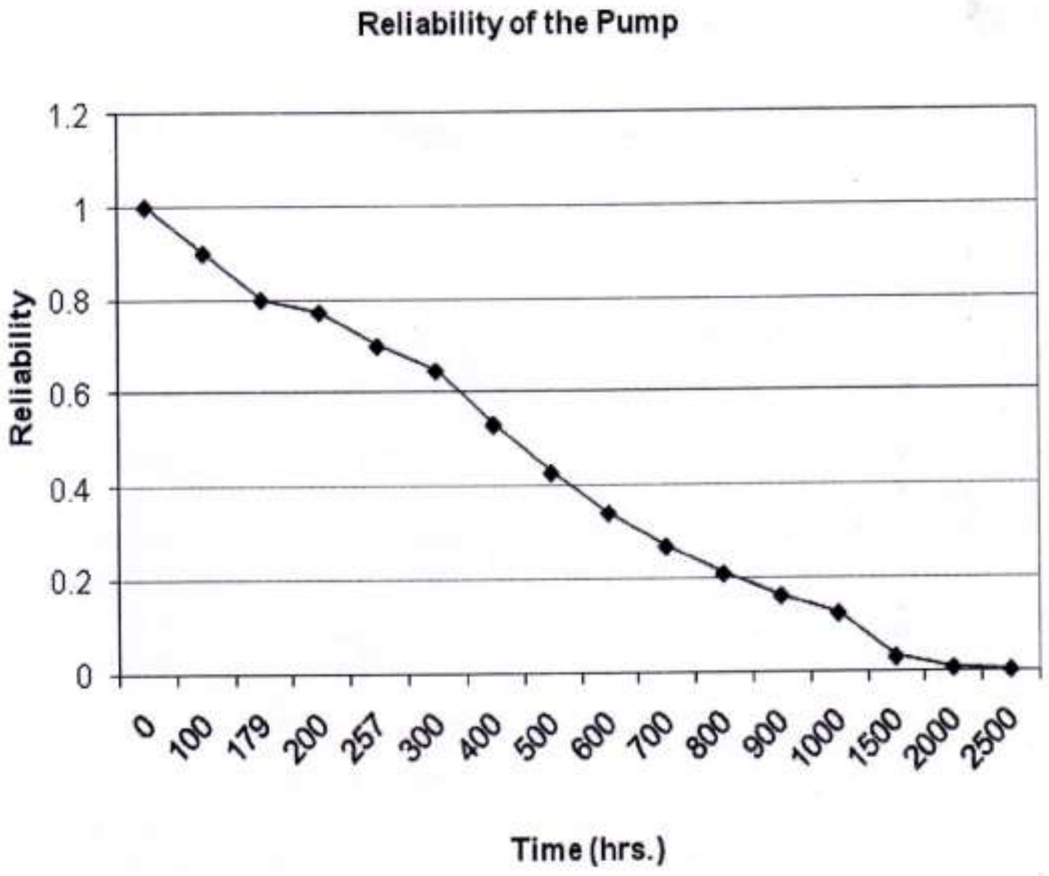

Fig. 3. Reliability of the HPP at various operation times

6. Reliability-based Preventive Maintenance Interval (PMI) estimation

As the shape parameter of the HPP is greater than one, i.e., â >1, then its failure rate is in the Increasing failure Rate (IFR) region. Therefore, PM is required to decrease its failure rate. The PM activity is carried out at predetermined time in order to reduce the probability of failure of any repairable system (Ghasrchami et al., 1998). Here PMIs may be set at higher reliability level considering maintenance cost, and other influencing factors which are not considered here. PMI at various reliability levels is shown in the Table 4 below.

Table 4. PMI at various reliability levels

Reliability levels of PMI	90% Reliability	80% Reliability	75% Reliability
PMI (hrs.)	100	179	257

7. Failure Mode Analysis for Inspection Planning.

Failure mode causes and effect analysis for all the components of HP pump is shown in the Table 5 below.

Table 5 : FAILURE MODE, CAUSES AND EFFECT ANALYSIS

Sl No	**Failure Modes**	**Causes**	**Effects**
1.	Bearing oil	Oil is black colour	H.P pump failure
2.	Gland leakage in cylinder	Slurry passing from gland seal	H.P pump failure
3.	Seal leakage	Seal worn out	H.P pump failure
4.	Oil strainer not working properly	Strainer worn out	H.P pump failure
5.	NRV block damage	Block worn out	H.P pump failure
6.	Plunger seal leakage	Seal worn out	H.P pump failure
7.	Plunger damage	Plunger worn out	H.P pump failure
8.	Gland pusher stud	Gland pusher stud thread damage	H.P pump failure
9.	Water pipe line leakage	Water pipe line rupture due to internal corrosion	H.P pump failure
10.	Stage block of cylinders damage	Worn out	H.P pump failure
11.	Bush bearing not working	Races worn out	H.P pump failure
12.	Slurry passing from gland seal	Seal become loose	H.P pump failure
13.	V – belt poor condition loosening	Belt worn out &	H.P pump failure
14.	Pump lub oil filter failure	Filter damaged	H.P pump failure
15.	Gland waterline chocked/ plunger damage	water pipe line rupture & Plunger worn out	H.P pump failure
16.	Carbon ring damage	Ring cracked	H.P pump failure
17.	Gland cooling system leakage	Pipeline cracked	H.P pump failure
18.	Gland cooling system & pipe line cleaning	Dusty pipeline	H.P pump failure
19.	Lub oil strainer cylinder plunger key damaged	Key damaged	H.P pump failure

Conclusions

The HPP has increasing failure rate. Therefore, PM is required to decrease its failure rate. Without considering the cost of maintenance, the PM may be scheduled with PMI of 257 hours, based on 75% reliability level. Further, considering the cost of maintenance and reliability simultaneously, the PM may be scheduled. The PM of the other components may be scheduled also using the same strategy.

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