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Mathematical Evaluation of Scale Factor and Shape Factor for Reliability Analysis of Ball Mill in Paint Manufacturing Unit

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Abstract:

The growths of present day industries are forced towards the use of more complex system. The production system consists thousands of parts and components and the failure of one or more component may lead to affect the entire production system. So with increase in automation and usage of complex systems, evaluation of reliability has recently been recognized for effective maintenance. Reliability has been evaluated mostly for mechanical components since and presently we are going to calculate Reliability for components in process industry. For this purpose, the break down time is calculated from Paint Industry. The data to be analyzed and reliability is calculated for each component by weibull distribution in probability is analyzed and criticality of each component is found by mathematical evaluation of shape factor and scale factor to suggest some of the preventive maintenance schedules.

Keywords: Reliability, Weibull, Availability, Shape factor & Scale factor.

I. INTRODUCTION

Machinery of different types whether cheap or costlier, heavy or small, simple or complex is prone to breakdowns. So, in every sector of modern industries whether manufacturing, transport, railways and supply, A definite maintenance schedule or procedure should be considered during the capacity planning and activity scheduling [1]. The main objective of maintenance is to increase the performance of equipment by definitely reducing the failures, faults or breakdowns by effectively adopting the proper maintenance schedules [2]. Due to increased breakdowns and failures the cost of production has been increased and the production capacity gets decreased. By suitable maintenance schedule or program breakdowns can be effectively controlled. The maintenance schedule includes like as lubrication, replacing filters, cleaning and adjusts settings [3]. During literature survey various studies had been conducted for the development and implementation of various mathematical models for maintenance schedules or programs; various mathematical models play an important role in overall development of maintenance plan [4]. During various researches many mathematical models are developed for continuous running machines and intermittent machines; the researches revealed that for intermittent running machines it is assumed that the system to age deteoriates only during the operating periods [5]. In field of machines reliability, maintenance is defined as an activity carried out for better machine performance [6]. In real practice it is a chance that the real tool life rarely matches with the forecasted values, for the prediction of machines or tool life Weibull distribution has been selected as the best model. In reliability studies Weibull Distribution plays an vital role [7].For the life data analysis, Weibull distribution plays an important role and fits best for the reliability prediction of an machine. Weibull distribution includes two important parameters shape factor **(β)** and scale parameter **(α).**The trace of physical failures is represented by factor β and time to failure by scale factor (α). The slope β also indicates the behavior of failure

β<1 indicates infant mortality

β = 1 indicates random failures

β> 1 indicates wear out [8]

In various mechanical failures it has been observed that machines degrade according to severity. If the fault is diagnosed at early stages, major repairs can be controlled or prevented [9].

It has been observed that the greatest risk of failures occurred at the early period of its installation; this occurs due to some internal defects present in the machines or components. If machine or component survived through this phase then it enters into stable phase with fewer failures, the stable period does not long fully but a final stage comes when the chance of failure starts again. On plotting these stages, the curve obtained is known as **"Bath tub curve"** [10].

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In 1951, Wallodi Weibull set up an mathematical model known as Weibull Distribution, which is an empirical relation that relates the data of the machines working with time.[11].

In manufacturing procedures through proper design and customer satisfaction, Reliability is one of the measure of quality and essential element for the equipment [12]. The probability for the machine that it will not fail is known as reliability. Reliability has been defined as the probability that a machine or unit perform its desired functions under its operating conditions. The probability function mathematically is defined as

$$\mathbf{F\ (t) = 1 -} = e^{-(t/n)^{\beta}} \quad [13]$$

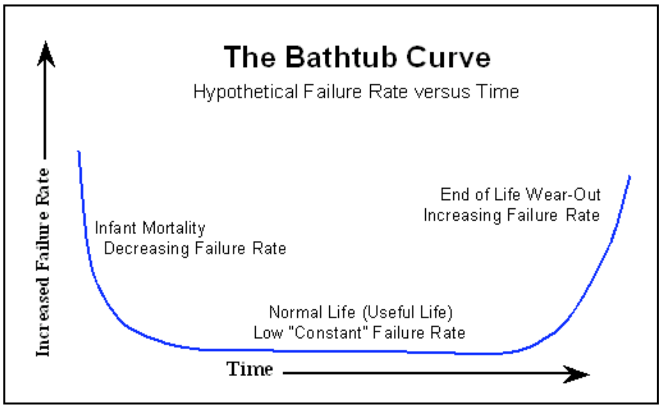

Figure 1 Bath Tub Curve

II. METHODOLOGY

The methodology followed to achieve is as follows:

1.The historical failure data, the down time and the availability of the equipment is collected.

2.From the past failure data, the down time and the availability of the equipment is calculated.

3.Weibull statistical distribution is used to model the failure history.

4.Using the parameters of weibull distribution the estimation of reliability has been carried out.

2.1 Mean Time Between Failures [MTBF]

The mean time between failures refers to average time of breakdown until the device beyond Repair. The mean time between failures is one of the useful terms in maintenance and reliability analysis.

$$\mathbf{MTBF} = \frac{\mathbf{OperatingTime}}{\mathbf{Numberoffailures}}$$

A. *Availability*

Availability of the system be the probability that a system or equipment shall operate satisfactorily and in an actual supply environment at any given time.

$$\mathbf{A} = \frac{\mathbf{MTBF}}{\mathbf{MTBF + MDT}}$$

Where MTBF Mean Time Between Failures, MDT Mean Down Time

B. *Estimation of operational availability*

Downtime of Ball mill has been calculated and tabulated with the help of the data collected. Table 4.2 shows the downtime of the various components from March'04 to May'04

C. *Reliability Estimation*

Reliability, which is a measure of quality, is an essential element at each stage of the equipment manufacturing procedure through design and production to final delivery to the user. Reliability, it is simplest form, means the probability that a failure may not occur in a given time interval. A more rigorous definition of reliability is a follows “Reliability of a unit (or product) is the probability that the unit performs its intended function adequately for a given period of time under the stated operating conditions or environment”. Reliability characteristics, such as probability of survival, mean time to failure, availability, mean down time and frequency of failures are some of the measures of system effectiveness. Apart from the above factors, reliability does change due to other factors like quality, workmanship, manufacturing process, material, storage, handling, engineering changes, and deviations in production, inspection and test.

The systems reliability $\mathbf{R\ (t)} = e^{-(t/\alpha)^{\beta}}$
Where,

α = Scale factor β = Shape factor **t** = Mean time

D. *Mathematical analysis for weibull parameters for Ball mill*

We know that according to rank regression formula

$$r(j) = r(j-1) + \frac{N+1 \quad -r(j-1)}{N+1 \quad -r(k_j-1)}$$

From ball mill table

N = 36

J = 1 to 11

K = 1 to 36 as N = 36

$$r(1) = r(1-1) + \frac{36+1 \quad -r(1-1)}{36+1 \quad -(5-1)}$$

$$r(1) = 0 + \frac{37 \quad -0}{37 \quad -4}$$

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$r(1) \quad = 37/33$

$$\boxed{\boldsymbol{r(1) = 1.121}}$$

$r(2) \quad = r(2-1) + \frac{37 \quad -r(2-1)}{37 \quad -(7-1)} = r(1) + \frac{37 \quad -r(1)}{37 \quad -6}$

$r(2) \quad = 1.121 + \frac{37 \quad -1.121}{31}$

$$\boxed{\boldsymbol{r(2) = 2.27}}$$

$r(3) \quad = r(2) + \frac{37 \quad -r(2)}{37 \quad -12}$

$= 2.27 + \frac{37 \quad -2.27}{25}$

$$\boxed{\boldsymbol{r(3) = 3.65}}$$

$r(4) \quad = r(3) + \frac{37 \quad -r(3)}{37 \quad -14}$

$= 3.65 + \frac{37 \quad -3.65}{23}$

$$\boxed{\boldsymbol{r(4) = 5.1}}$$

$r(5) \quad = r(4) + \frac{37 \quad -r(4)}{37 \quad -19}$

$= 5.1 + \frac{37 \quad -5.1}{18}$

$$\boxed{\boldsymbol{r(5) = 6.87}}$$

$r(6) \quad = r(5) + \frac{37 \quad -r(5)}{37 \quad -20}$

$= 6.87 + \frac{37 \quad -6.87}{17}$

$$\boxed{\boldsymbol{r(6) = 8.64}}$$

$r(7) \quad = r(6) + \frac{37 \quad -r(6)}{37 \quad -21}$

$= 8.64 + \frac{37 \quad -8.64}{16}$

$$\boxed{\boldsymbol{r(7) = 10.41}}$$

$r(8) \quad = r(7) + \frac{37 \quad -r(7)}{37 \quad -24}$

$= 10.41 + \frac{37 \quad -10.41}{13}$

$$\boxed{\boldsymbol{r(8) = 12.45}}$$

$r(9) \quad = r(8) + \frac{37 \quad -r(8)}{37 \quad -27}$

$= 12.45 + \frac{37 \quad -12.45}{10}$

$$\boxed{\boldsymbol{r(9) = 14.90}}$$

$r(10) \quad = r(9) + \frac{37 \quad -r(9)}{37 \quad -31}$

$= 14.90 + \frac{37 \quad -14.90}{6}$

$$\boxed{\boldsymbol{r(10) = 18.58}}$$

$r(11) \quad = r(10) + \frac{37 \quad -r(10)}{37 \quad -32}$

$= 18.58 + \frac{37 \quad -18.58}{5}$

$$\boxed{\boldsymbol{r(11) = 22.26}}$$

1. $v_j \quad = l_n\left(l_n\left(\frac{1}{1-\frac{r(i)-0.3}{36.4}}\right)\right)$

$= l_n\left(l_n\left(\frac{1}{1-\frac{1.121-0.3}{36.4}}\right)\right)$

$= l_n\left(l_n\left(\frac{1}{0.977}\right)\right)$

$= l_n\left(l_n(1.023)\right) =$ -3.816

2. $= l_n\left(l_n\left(\frac{1}{1-\frac{2.27-0.3}{36.4}}\right)\right)$

$= l_n\left(l_n\left(\frac{1}{0.945}\right)\right)$

$= l_n\left(l_n(1.058)\right)$

$= l_n(0.056) =$ -2.88

3. $= l_n\left(l_n\left(\frac{1}{1-\frac{3.65-0.3}{36.4}}\right)\right)$

$= l_n\left(l_n\left(\frac{1}{0.907}\right)\right)$

$l_n\left(l_n(1.102)\right)$

$= l_u(0.097) =$ -2.33

4. $= l_n\left(l_n\left(\frac{1}{1-\frac{5.1-0.3}{36.4}}\right)\right)$

$= l_n\left(l_n\left(\frac{1}{0.868}\right)\right)$

$= l_n\left(l_n(1.152)\right)$

$= l_n(0.1414) =$ -1.95

5. $= l_n\left(l_n\left(\frac{1}{1-\frac{6.87-0.3}{36.4}}\right)\right)$

$= l_n\left(l_n\left(\frac{1}{0.819}\right)\right)$

$= l_n\left(l_n(1.22)\right)$

$= l_n(0.198) = -1.619$

6. $= l_n\left(l_n\left(\frac{1}{1-\frac{8.64-0.3}{36.4}}\right)\right)$

$= l_n\left(l_n\left(\frac{1}{0.77}\right)\right)$

$= l_n\left(l_u(1.29)\right)$

$= l_n\left(l_n(0.254)\right) = 1.37$

7. $= l_n\left(l_n\left(\frac{1}{1-\frac{10.41-0.3}{36.4}}\right)\right)$

$= l_n\left(l_n\left(\frac{1}{0.722}\right)\right)$

$= l_n\left(l_n(1.385)\right)$

$= l_n(0.325) = -1.123$

8. $= l_n\left(l_n\left(\frac{1}{1-\frac{12.45-0.3}{36.4}}\right)\right)$

$= l_n\left(l_n\left(\frac{1}{0.666}\right)\right)$

$= l_n\left(l_n(1.501)\right)$

$= l_n(0.406) = -0.901$

9. $= l_n\left(l_n\left(\frac{1}{1-\frac{14.90-0.3}{36.4}}\right)\right)$

$= l_n\left(l_n\left(\frac{1}{0.598}\right)\right)$

$= l_n\left(l_n(1.672)\right)$

$= l_n(0.514) = -0.665$

10. $= l_n\left(l_n\left(\frac{1}{1-\frac{18.58-0.3}{36.4}}\right)\right)$

$= l_n\left(l_n\left(\frac{1}{0.497}\right)\right)$

$= l_n\left(l_n(2.012)\right)$

$= l_n(0.699) = -0.358$

11. $= l_n\left(l_n\left(\frac{1}{1-\frac{22.26-0.3}{36.4}}\right)\right)$

$= l_n\left(l_n\left(\frac{1}{0.396}\right)\right)$

$= l_n(2.525)$

$= l_n(0.926) = -0.076$

β $= \frac{11\,x\,(-154.57)+(103.91)(17.088)}{11\text{ x }985.28 \quad (103.91)^2}$

$= \frac{75.34}{40.49} =$ **β = 1.847**

$$\alpha = exp\left[\frac{\left(\sum_{j=1}^{k} v_j\right)\ \left(\sum_{j=1}^{k} x_j{}^2\right)-\left(\sum_{j=1}^{k} x_j\right)\ \left(\sum_{j=1}^{k} x_j v_j\right)}{-\beta\left[k\sum_{j=1}^{k} x_j{}^2\ -\ \left(\sum_{j=1}^{k} x_j\right)^2\right]}\right]$$

α $= exp\left[\frac{-16836.46+16061.36}{-1.847\ [40.7919]}\right]$

$= exp\left[\frac{-775.1}{-75.34}\right]$

$= exp[10.288]$=29377.95hrs

The estimated weibull parameters for ball mill

β = shape factor = 1.847

α = scale parameter = 29377.95 hours

E. Reliability Estimation for Ball Mill

From Table
Shape Factor = β = **1.847**
Scale Parameter = α
α = **29377.95hours**
Mean time = t = 18223.5
Therefore **R (t) =**$e^{-(t/n)^{\beta}}$
R (t) =$e^{-(0.897)^{3.34}}$

R (t) =0.49 or 49%

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Table 1: Evaluation of parameter

$x_j = l_n(t_j)$	v_j $l_n\left(l_n\left(\frac{1}{1-\frac{j-0.3}{n+0.4}}\right)\right)$	$x_j v_j$	x_j^2
8.19	-3.816	-31.25	67.07
8.53	-2.88	-24.56	72.76
9.15	-2.33	-21.31	83.72
9.29	-1.95	-18.11	86.30
9.58	-1.619	-15.51	91.77
9.63	-1.37	-13.19	92.73
9.68	-1.123	-10.87	93.70
9.81	-0.901	-8.83	96.23
9.92	-0.665	-6.59	98.40
10.05	-0.358	-3.59	101.00
10.08	-0.076	-0.76	101.60
$\sum x_j = \mathbf{103.91}$	$\sum v_j = \mathbf{-17.088}$	$\sum x_j v_j = \mathbf{-154.57}$	$\sum x_j^2$=**985.28**

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Table-2 Cumulative failure for Ball Mill

S.No.	Month	Monthly Operating Time (Hours)	Cumulative monthly operating time (Hours)	Down Time	No. of failures	% Failures	% Cumulative Failures
1.	Jan	744	744	0	0	0	0
2	Feb	672	1416	0	0	0	0
3.	Mar	744	2160	0	0	0	0
4.	Apri	720	2880	0	0	0	0
5.	May	744	3624	54	5	19.23	19.23
6.	June	720	4344	0	0	0	19.23
7.	July	744	5088	20	1	3.84	23.07
8.	Aug	744	5832	0	0	0	23.07
9.	Sept	720	6552	0	0	0	23.07
10.	Oct	744	7296	0	0	0	23.07
11.	Nov	720	8016	0	0	0	23.07
12.	Dec	744	8760	0	0	0	23.07
13.	Jan	744	9504	40	1	3.84	26.91
14.	Feb	672	10176	0	0	0	26.91
15.	Mar	744	10920	38	2	7.69	34.6
16.	Apri	720	11640	0	0	0	34.6
17.	May	744	12384	0	0	0	34.6
18.	June	720	13104	0	0	0	34.6
19.	July	744	13848	0	0	0	34.6
20.	Aug	744	14592	45	2	7.69	42.29
21.	Sept	720	15312	20	1	3.84	46.13
22.	Oct	744	16056	20	1	3.84	49.97
23.	Nov	720	16776	0	0	0	49.97
24.	Dec	744	17520	0	0	0	49.97
25.	Jan	744	18264	20	1	3.84	53.81
26.	Feb	672	18936	0	0	0	53.81
27.	Mar	744	19680	0	0	0	53.81
28.	Apri	720	20400	30	2	7.69	61.5
29.	May	744	21144	0	0	0	61.5
30.	June	720	21864	0	0	0	61.5
31.	July	744	22608	0	0	0	61.5
32.	Aug	744	23352	18	1	3.84	65.34
34.	Oct	744	24816	0	0	0	99.9
35.	Nov	720	25536	0	0	0	99.9

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36.	Dec	744	26276	0	0	0	99.9

Conclusion

Keeping in view, all aspects of company's performance with particular reference to machine breakdowns or shut downs, it is of great interest to formulate the accurate maintenance policy to reduce the breakdowns, avoid shutdowns and increase the productivity of a manufacturing plant. To lead or sustain in the competition era, to sustain or achieve the production goals, A long term commitment; continuous monitoring of maintenance technology is required. By implementing a proper maintenance schedule and making full use of maintenance employees in the production process, an improvement has been observed in manufacturing process by effectively reduction in breakdowns. By reducing the machine breakdowns the availability and reliability of particular machine has been improved. Availability of data regarding the machines reliability is of considerable benefit to industry in many situations. The awareness of life expectancy and wear out characteristics of the system/ machine /component leads to the development of adequate maintenance policy or schedule. In our analysis it is possible to correlate the machines reliability with maintenance requirements. To achieve the efficient availability and reliability of machine or system it is very essential that responsibilities and role to maintenance department should be defined accurately and should be followed accordingly.

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