Scheduling of Preventive Maintenance for Iron-Ore Conveyor System

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Abstract: In this paper a preventive maintenance schedule is prepare for an iron-ore conveyor system. Basically in industry two types of maintenance: corrective and preventive maintenance is performed, corrective maintenance is performed on the failure and preventive maintenance is performed to avoid the failure. Due to the working condition and lake of proper maintenance, the failure occurs frequently faster than their designed life. The failure of mechanical component follows the Weibull distribution. On the basis of previous failure of the component of conveyor system, the preventive maintenance is scheduled. For these previous failures are collected and the shape & scale parameter is obtained using weibull-fit function in mat-lab. A program is prepared by the author for the PMS (preventive maintenance schedule) and TCPUT (total cost per unit time) on the input of shape parameter, scale parameter, some time factor (MTTR) and cost factor (C_f & C_{pm}). In such a way the schedule for preventive maintenance is prepare and TCPUT is obtained, and thus the frequency of corrective maintenance and its cost can be reduced.

Key-words: C_{pm}, C_f, Maintenance, MTTR.

Acronyms

PMS	Preventive Maintenance Schedule
TCPUT	Total Cost per Unit Time
MTTR	Mean Time to Repair
PM	Preventive Maintenance
CM	Corrective Maintenance

Notation

Cf	Cost of Failure
Cpm	Cost of Preventive Maintenance
Tpm	Time for optimum PM
R(Tpm)	Reliability at PM schedule
f(T)	Probability of failure at time T
R(T)	Reliability at time T
β	Shape parameter
η	Scale parameter

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I. INTRODUCTION:

To run the plant, it is required that the each machine should run properly, for the continuous running of machine its maintenance is required. On today generally 60-70 % cost of overall cost is the maintenance cost, so concentrating with reduction of maintenance cost is beneficial [1]. Basically the maintenance can categorize in; corrective maintenance and preventive maintenance. The corrective maintenance performed in the case of failure and preventive maintenance performs to avoid failure for the proper running of plant. In corrective maintenance major repair and the replacement of spare parts are performed while in preventive maintenance minor repair and oiling, greasing and alignment such type of work is performed [2],[3].

The cost associated with corrective maintenance is the cost of failure (C_f) and the preventive maintenance associated cost is the cost of preventive maintenance (C_{pm}). It is clear that cost of failure (C_f) is much higher than the cost of preventive maintenance (C_{pm}). For the reduction in cost, in production, maintenance cost is an important factor which has to be reduced for the reduction of maintenance cost.

On the performance of preventive maintenance the corrective maintenance frequency can be reduce, and by optimum preventive maintenance schedule; preventive maintenance frequency and its cost can also be reduced. Thus by applying optimum preventive maintenance schedule, the production cost is reduced; due to the reduction of maintenance cost. When failures occur, its need to be repair or replacement, the time consumed for this is known as repair time.

MTTR is the average time which is consumed during the repair of a machine component when failure occurs. It is an important factor while calculating the TCPUT.

II. WEIBULL DISTRIBUTION:

For modelling purposes the Weibull distribution has been chosen. This distribution most frequently provides the best fit of life data. It has practical utility-ability to model systems irrespective of electrical/mechanical devices consisting of large number of components and may have increasing/decreasing or a constant failure rate.

Weibull distribution is described by its probability density function with two parameters, shape parameter (β) and scale parameter(η). Its *pdf is* given by [4]:

$$f(T) = w(\beta, \eta) = \frac{\beta}{\eta} \times \left(\frac{T}{\eta}\right)^{\beta-1} \times e^{-\left(\frac{T}{\eta}\right)^{\beta}}$$

The reliability function of Weibull distribution is given by:

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

Shape parameter determines the nature of failure rate viz. constant, increasing or decreasing.

$\beta < 1$ *indicates Decreasing failure rate.*
$\beta = 1$ *indicates Constant failure rate.*
$\beta > 1$ *indicates Increasing failure rate.*

III. TCPUT:

To determine the optimum time for a preventive maintenance action, we need to mathematically formulate a model that describes the associated costs and risks. In developing the model, it is assumed that if the unit fails before time *t*, a corrective action will occur and if it does not fail by time *t*, a preventive action will occur.

$$TCPUT = \frac{\textbf{Total Expected PM cost per cycle}}{\textbf{Expected cycle length}}$$

$$\begin{aligned} \textbf{Total Expected PM cost per cycle} &= \textbf{Preventive maintenace cost} \\ &\times \textbf{Probability of servival up to } T_{PM} \\ &+ \textbf{Failure cost} \\ &\times \textbf{Probability of failing up to } T_{PM} \end{aligned}$$

$$\begin{aligned} \textbf{Expected Cycle Length} &= \textbf{Expected length of PM cycle} \\ &\times \textbf{Probability of servival up to } T_{PM} \\ &+ \textbf{Expected length of PM cycle} \\ &\times \textbf{Probability of failing up to } T_{PM} \end{aligned}$$

Thus, the optimum PM time can be found by minimizing the cost per unit time, *TCPUT (T)* (Kulkarni, 1999), is given by [5]:

$$TCPUT = \frac{C_{PM} \times R(T_{PM}) + C_f[1 - R(T_{PM})]}{(T_{PM} + MTTR) \times R(T_{PM}) + \left[MTTR + \frac{1}{1 - R(T_{PM})} \times \int_0^{T_{PM}} T.f(T)dt\right] \times 1 - R(T_{PM})}$$

In this paper iron-ore conveyor system of blast furnace is considered for the preventive maintenance scheduling. This conveyor system is used to transport the iron-ore from stock-yard (after crushing & screening if required) to the blast furnace. Due to the continuity of steel production, the conveyor system should run continuously. The large scale plant has more number of conveyor systems and small scale plant has some number of conveyor systems, it depends on the company policies and the available capital. But ultimately the conveyor system required maintenance. To maintain the conveyor system, the maintenance of each component of conveyor system is required. The components of iron-ore conveyor system are shown in fig.

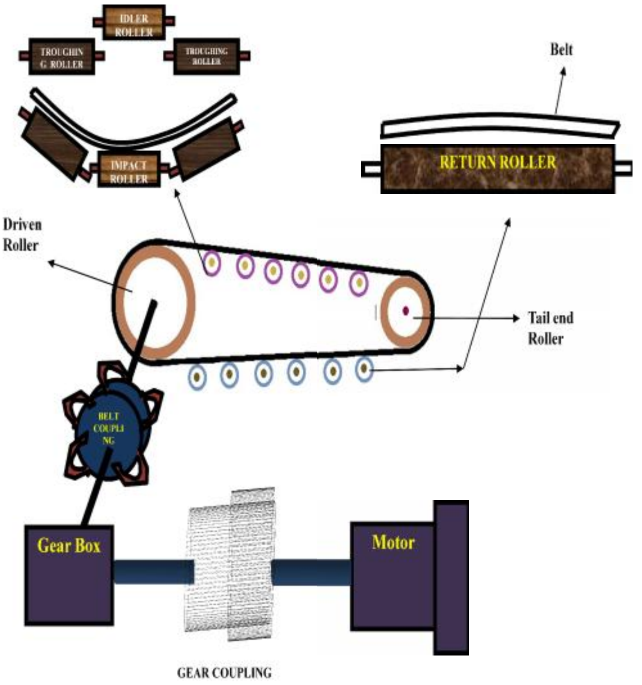

Fig. Conveyor System Component

In conveyor system the main parts are require some preventive action as mentioned below:

Sl No.	Component	Preventive Maintenance Action
1	BELT	Obstacle should have remove, prevent from cut by any type of sharp edge.
2	IDLER ROLLER	To check that it should proper placed on the grooves.
3	RETURN ROLLER	To check that it should proper placed on the grooves.
4	GEAR BOX	Oiling, Greasing, alignment with shaft of gear coupling.
5	BELT COUPLING	To tighten the bolt, maintain the distance between the flanges.
6	GEAR COUPLING	Oiling, Greasing, alignment of the coupled shaft.

IV. METHODOLOGY:

A. Collection of failure data of each component.

```
disp('BELT')
B=xlsread('CCD.xls',1,'b4:b25')';
B=B(B~=0);
parameter=wblfit(B);
eta=parameter(1)
beta=parameter(2)
```

B. Calculating the value of β & η from the failure data using weibull-fit (mat-lab).
C. Develop a program for the PMS in Mat-lab, using the input data of β & η C_f, C_{pm} & MTTR.
D. PMS is obtained for each component, it can be manually calculated the PMS for whole conveyor system.

Collection of failure data of each component [table 1]:

The data given below is on the experience and log book of maintenance department. There are number of idler & return roller in a conveyor system, in below data group of IR & RR are considered and the failure occurrence is according to that.

Table 1

Failure Data (Cumulative) Of Conveyor System (Hrs.)

Sl No.	Belt	Idler Roller	Return Roller	Gear box	Belt Coupling	Gear coupling
1	3847	3428	4373	9456	8744	8544
2	6938	7754	7273	18264	15804	15504
3	10226	10834	11822	26520	22656	22656
4	13857	14536	13827	33480	30896	30096
5	16483	18736	17632	38472	37827	38616
6	19837	21928	21837	44616	43872	45456
7	22843	24938	25617	51552	51926	51864
8	26373	27816	28736	60840	58756	58488
9	29487	32166	32817	69120	66374	66120
10	32948	35653	35717	78768	73473	73176
11	35867	38726	39827	88536	81635	81048
12	39228	41327	43872	95496	87924	87840
13	42536	45928	47829	102432	95125	94896
14	45897	48726	52837	109848	103214	101568
15	48736	52837	55638	116736	111008	109008
16	52343	55838	58272	122856	119143	117168
17	56747	59322	62837	130608	125143	124128
18	59837	63724	64562	139632	132182	131016
19	62838	67352	67542	145248	138222	137296
20	65774	71625	72837	153528	145525	143504

By putting above failure record in mat-lab using weibull-fit, the algorithm for belt is following:

In similar manner, for all the component the shape parameter & scale parameter is calculated.

Result	Belt	Idler Roller	Return Roller	Gear box	Belt Coupling	Gear coupling
beta =	1.8543	1.8479	1.8451	1.8961	1.8403	1.8871
eta =	38852	41631	42937	91902	86942	86292

For the PMS and to evaluate the TCPUT, required data are mentioned in table:

	Belt	Idler Roller	Return Roller	Gear box	Belt Coupling	Gear coupling
beta =	1.8543	1.8479	1.8451	1.8961	1.8403	1.8871
eta =	38852	41631	42937	91902	86942	86292
Cf (Rs)	350000	27000	22000	1000000	21000	110000
Cpm (Rs)	1500	200	200	1200	150	450
MTTR (Hr)	10	1.2	1.5	2.5	0.4	0.8

For the PMS and to evaluate the TCPUT, a program is prepared in mat-lab.

```
beta=xlsread('CCD.xls',2,'b2:g2');
eta=xlsread('CCD.xls',2,'b3:g3');
Cf=xlsread('CCD.xls',2,'b4:g4');%cost of
failure
Cpm=xlsread('CCD.xls',2,'b5:g5');%cost of
preventive maintenance
MTTR=xlsread('CCD.xls',2,'b6:g6');%mean
time to replacement
i1=0;
Tpm=180:25:100000;
for a=1:length(beta)
    i=1;
    Tpm=180; %12=Tpm
    while Tpm<=100000

        Tpm=Tpm+25; %12=Tpm
        x=linspace(i1,Tpm,30000);

y=x.*(beta(a)/eta(a).*((x/eta(a)).^(beta(
a)-1)).*(exp(-(x/eta(a)).^beta(a))));
        z=trapz(x,y);
        RTpm=exp(-
((Tpm/eta(a))^beta(a)));

numerator=(Cpm(a)*RTpm)+(Cf(a)*(1-RTpm));

denominator=((Tpm+MTTR(a))*RTpm)+((1-
RTpm)*(MTTR(a)+(1/(1-RTpm))*z));
        TCPUT(i)=numerator/denominator;
        i=i+1;
        plot(TCPUT)
    end
    TCPUT;
    tcput(a)=(min(TCPUT));
    index=(find(TCPUT==(min(TCPUT))));
    opt_Tpm(a)=(index);
end
fprintf('\n Optimum PM Schedule   \n')
opt_Tpm'
fprintf('\n TCPUT    \n')
tcput'
```

V. RESULT:

The result from the above program for PMS and TCPUT are obtained:

Result	Belt	Idler Roller	Return Roller	Gear box	Belt Coupling	Gear coupling
OPM Schedule (Hrs.)	82	121	141	105	255	193
TCPUT (Rs./Hr)	1.447	0.135	0.118	0.903	0.050	0.191

VI. CONCLUSION:

1. By the analyzing the previous data, it is possible to reduce the occurrence of failure by applying effective maintenance schedule.

2. On the performance of the Optimum preventive maintenance:
    - Failure occurrence can be reduced.
    - The reliability is improved.
    - Costs are also reduced.

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