Formulation of Preventive Maintenance Schedule for Dragline System

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***Abstract*—Dragline system is a high capacity, capital intensive and specialized mining equipment in Open Cast Mines that are used to extract coal by removing overburden. It consists of six sub-systems namely Drag, Hoist, Swing, Power Drive, Propel &others. It is essential that all the subsystems remain in operating state for maximum possible time duration for efficient working of the dragline system. A typical dragline can move about 3 crore cubic metres of overburden a year [2] and equates to generate approximately 1 lac revenue per hr. Existing reliability for subsystem drag and hoist are 0.4742 (47.42%) and 0.5931 (59.31%) respectively. This paper outlines determination of improvement potential of reliability of drag and hoist. Mean Time Between Failure (MTBF) is calculated for failure component of drag and hoist. An entire dragline needs to be stopped for execution of any preventive maintenance action. Age replacement policy is suggested for critical failure component. Minimum MTBF is for spare link which is 3.31 months whereas MTBF for drag rope and O ring is 3.42months and 3.63 months respectively. It is suggested to replace drag rope and o ring at 3.31 month along with spare link that shall cause net saving potential of 9.5 lacs / year**

***Index Terms*— Age replacement policy, Dragline, MTBF, Preventive Maintenance, Reliability improvement.**

I. Introduction

During the past few years, the business environment in which coal mines prevail has undergone and experienced sea changes due to pressure from industry, competitors and regulatory body. Dragline is the high capacity, capital intensive and specialized mining equipment used for removal of overburden in opencast coal mine. Coal is very important with main purpose of generating electricity through thermal power plant. Performance of a dragline system depends on reliability, availability & maintainability characteristic of the system & its six sub-systems such as drag, hoist, swing, propel, power drive & others. If Failure occurs in the component of any subsystem of the dragline, it results in the stoppage of entire dragline system [1]. The dragline system cost is in the vicinity of 100 crores. Hence reliability modeling of dragline system is utmost important. From the field data book breakdown time is recorded for a period of about three years .Breakdown time for two major subsystems, namely drag and hoist are recorded more. It is observed that breakdown time is more for drag and hoist and hence they are selected as a subsystem for reliability modeling and further determination of improvement potential. Failure Data Analysis acts as a very important tool for Reliability Modeling of Dragline System [3]. Failure data collected from the field is fitted for suitable conventional type of distribution namely Normal distribution, lognormal distribution, Exponential distribution and Weibulll distribution.[6] For subsystems Drag and Hoist, Mean Time To Failure (MTTF) is greater than Median and approximately not equal to standard deviation(σ). Therefore lognormal distribution & weibull distribution will provide better fit [8][9]. After carrying out entire analysis, index of fit (r) for drag by Weibull distribution is 0.1674 and by lognormal distribution is 0.00013. Similarly index of fit for hoist by Weibull distribution is 0.2191 and by lognormal distribution is 0.0108 [10]. Since values of index of fit are very less, they are not considered as the distribution fitting to the failure times. The Operating Time before Failure (OTBF) is not homogenous. Therefore Non-Homogenous Poisson (NHP) process is considered as a model befitting to the Situation. The reliability of the drag is found to be 0.4742 (47.42%) and the reliability of the hoist is found to be 0.5931 (59.31%) by the application of this methodology [10].

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II. Improvement Potential Of Reliability

A. Methodology:

Methodology for determination of improvement of reliability is outlined as indicated herein,

a. Identification of critical failure components along with failure time and frequency of failure.
b. Determination of existing MTBF of failure components.
c. Estimation of total working time of drag and hoist with and without failure.
d. Estimation of modified MTBF based on No failure condition.
e. Estimation of reliability based on modified MTBF.
f. Determination of reliability improvement potential.

B. Analytical Estimation

Reliability improvement potential is estimated for subsystem drag and hoist considering

i. Failures in individual component
ii. Removal of failures in entire system

as given below.

1: Drag:

i. Reliability improvement potential considering failures in individual system:

TABLE I: FREQUENCY OF FAILURE- DRAG

SN	Critical Failure Component	Failure Time (Hrs)	Frequency of Failure
01	Drag Rope	63.5	10
02	Spare Link	9	10
03	O Ring	16.5	7
04	Drag Bracket	8.5	4
05	Drag Brake	2	2
SUM		99.5	33

Failure Component: Drag Rope

Total Failure Time of drag Rope = 63.5 hrs.
Mean Time Between Failure ,
MTBF (T+t, T) = (T+t,-T) / m(T+t, T)
= 586.5 / 0.7461 = 786.08 hrs. [10]
Total working Time of Drag = MTBF x [No. of Failure +1]
= 786.08 x 41 [10]
= 32229.59 hrs.
No. of Failures of drag rope = 10
Assuming that there is no failure of drag rope then,
No. of failures = 40 – 10 = 30
Therefore,
New Total Working Time
= Total working Time of Drag + Total Failure Time drag Rope
= 32229.59 + 63.5 = 32293.09 hrs.
New Mean Time Between Failure,
MTBF = 32293.09 /30 = 1076.436 hrs.
New m(T+t, T) = 586.41 / 1076.436 = 0.5448
Therefore, Improved reliability
$= e^{-m\,(T+t,\,T)}$ [8]
$= e^{-0.5448}$ = 0.5799 = 57.99%

Similarly Improved reliability for critical failure components namely spare link, O ring, drag Bracket, drag brake are estimated as 57.94%, 54.87%, 51.95% and 50.08% respectively

Thereby calculating reliability improvement potential as follows:

TABLE II: RELIABILITY IMPROVEMENT POTENTIAL- DRAG

SN	Failure Component	Modified System Reliability	Reliability Improvement
01	Drag Rope	57.99	10.57 %
02	Spare Link	57.94	10.52 %
03	O Ring	54.87	7.45 %
04	Drag Bracket	51.97	4.5 %
05	Drag Brake	50.08	2.6 %

ii.Reliability improvement potential considering removal of failures in system:

Total Failure Time of critical failure component = 99.5
Mean Time Between Failure,
MTBF (T+t,T) = (T+t,T)/ m(T+t,T)
= 586.5/0.7461 = 786.08 hrs. [10]
Total working Time = MTBF x [No. of Failure +1]
= 786.08 x 41 = 32229.59 hrs. [10]
No. of critical failures of drag = 33
Assuming that there is no failure of critical failure component, then
No. of failures = 40 – 33 = 07
Therefore, New Total Working Time
= Total working Time + Total Failure Time of critical failure component
= 32229.59 + 99.5 = 32329.09 hrs.
New Mean Time Before Failure,
MTBF =32329.09 / 07 = 4618.44 hrs.
New m(T+t, T) = 586.41 / 4618.44 = 0.1269
Therefore, Improved reliability
$= e^{-m\,(T+t,\,T)} = e^{-0.1269}$ =0.8807 = 88.07%
Overall Improvement of Reliability = 0. 8807 - 0.4742
(Due to control of all critical failures) = 0.4065 = 40.65 %

2: Hoist:

i. Reliability improvement potential considering failures in individual system:

TABLE III: FREQUENCY OF FAILURE- HOIST

SN	Critical Failure Component	Failure Time (Hrs)	Frequency of Failure
01	Spare Link	14.5	13
SUM		14.5	13

Failure Component: Spare Link

Total Failure Time of Spare Link = 14.5 hrs.
Mean Time Before Failure,
MTBF (T+t, T) = (T+t,-T) / m(T+t, T)
= 1328.5 / 0.5209 = 2550.39 hrs. [10]
Total working Time of Drag
= MTBF x [No. of Failure +1] =2550.39 x 15 [10]
= 38255.9 hrs.
No. of Failures of Spare Link = 13
Assuming that there is no failure of Spare Link then,
No. of failures = 14 – 13 = 01
Therefore, New Total Working Time
= Total working Time of Drag + Total Failure Time of Spare Link
= 38255.9 + 14.5 = 38270.40 hrs.
New Mean Time Before Failure,
MTBF =38270.40 / 01 = 38270.40 hrs.
New m(T+t, T) = 1328.5/ 38270.40 = 0.0347
Therefore, Improved reliability
$= e^{-m\,(T+t,\,T)} = e^{-0.0347}$ = 0.9658 = 96.58 %
Improved reliability for critical failure component spare link is 96.58 %.

TABLE IV: RELIABILITY IMPROVEMENT POTENTIAL- HOIST

SN	Failure Component	Modified System Reliability	Reliability Improvement
01	Spare Link	96.6	37.19 %

ii.Reliability improvement potential considering removal of failures in system:

Total Failure Time of critical failure component = 14.5 hrs.
Mean Time Before Failure,
MTBF (T+t, T) = (T+t,-T) / m(T+t, T)
= 1328.5 / 0.5209 = 2550.39 hrs.
Total working Time = MTBF x [No. of Failure +1]
=2550.39 x15 = 38255.9 hrs.
No. of critical failures of drag = 13

Assuming that there is no failure of critical failure component, then
No. of failures = 14 – 13 = 01
Therefore, New Total Working Time
= Total working Time + Total Failure Time of critical failure component
= 38255.9 + 14.5 = 38270.40 hrs.
New Mean Time Before Failure,
MTBF =38270.40 / 01 = 38270.40 hrs.
New m(T+t, T) = 1328.5/ 38270.40
= 0.0347
Therefore, Improved reliability
$= e^{-m(T+t,\ T)} = e^{-0.0347} = 0.9658 = 96.58\ \%$
Improvement of Reliability (due to control of critical failure component) = 0.9658 - 0.5939 = 0.3719 = 37.19 %
Improvement Potential of reliability for subsystems drag and hoist due to control of critical failure components are estimated as 40.65 % and 37.19 % respectively.

III. Reliability Improvement Potential Through Preventive Maintenance (PM)

Existing maintenance strategy encompasses the replacement of component on failure i.e. concept of breakdown maintenance. Hence it is suggested to introduce PM concept. Preventive maintenance is the performance of inspection and/or servicing tasks that have been preplanned (i.e. scheduled) for accomplishment at specific points in time to retain the functional capabilities of operating equipment or systems. It is useful in developing a proactive maintenance mode and culture. There are three reasons for doing preventive maintenance which are Prevention of failure, detection on set of failure, discovery of a sudden failure. After identifying the three reasons for doing preventive maintenance, task categories are universally employed in constructing a PM program irrespective of the methodology that is used to decide what PM should be done in the program. All preventive maintenance was premised on the basis that equipment could be periodically restored to like new condition several times before it was necessary to discard it for a new (or improved) item [7][5].

Methodology to establish preventive maintenance schedule for drag and hoist is as outlined below,

1. Estimation of Mean time Between Failure (MTBF) for all the significant failure.
2. Identification of MTBF value within the close vicinity.

Schedule the Preventive Maintenance action for the component having MTBF value within the close vicinity.

Mean time between the failures (MTBF) for the critical failure components is estimated by failure data analysis for the failure data of about 3 years [3] as shown in table

TABLE V: Mean Time Between Failure

SN	Subsystem	Failure Component	MTBF (Month)
01	Drag	Drag Rope	3.42
		Spare Link	3.31
		O Ring	3.63
		Drag Bracket	4.56
		Drag Brake	12.32
02	Hoist	Spare Link	2.66

It is observed that the values of mean time between failure for critical failure components namely drag rope, spare link and O ring are in the close vicinity. The least value of MTBF is for spare link i.e 3.31 month. The entire dragline needs to be stopped for execution of any preventive maintenance action. It is proposed that the preventive maintenance action in order to minimize the recurrence of failure is to be performed at the same time to minimize preventive maintenance downtime cost. Hence preventive maintenance schedule along with the maintenance action is developed as shown in Table.

TABLE VI: Suggested Preventive Maintenance Schedule

SN	Subsystem	Failure Component	Frequency	PM Action
01	Drag	Drag Rope	10	Replace after 3.31 Months
		Spare Link	10	Replace after 3.31 Months
		O Ring	7	Replace after 3.31 Months
		Drag Bracket	4	Replace after 4.56 Months
		Brake Drum	2	Replace after 12.32 Months
02	Hoist	Spare Link	13	Replace after 2.66 Months

IV. Economic Analysis As Per Age Replacement Policy

The Average age of critical failure component drag rope is 3.42 months. If drag rope is replaced after 3.31 months, 0.11 months is the loss of usage of the system but downtime is saved by 0.11 months. The three critical failure components viz. drag rope; spare link and O ring have average downtime in the closed vicinity and hence should be replaced at the same time. Net saving by age replacement policy is estimated as outlined herein [4].

1. Total Loss to be incurred due to
= (Average Time of repairs of three failure breakage of three components) x downtime cost / hour.
= (2.83 +0.9+2.357) x 100000
= Rs.6,08,700
2. Cost due to replacement of all the three components at a time
= (2.83 x 100000) + ((0.11 x2,14,500)/3.42) + ((0.32x 16000)/3.63)
= 2,83,000 +6899.12+1410.46 = Rs. 2,91,309.59
Where Cost of drag rope = Rs.2,14,500
Cost of O Ring = 16000 Rs.
3 .Net Saving =Loss to be incurred - Cost due to replacement
= Rs.6,08,700 - Rs. 2,91,309.59
= Rs. 3,17,390.41(over a period of approximately 4 months)
= Rs. 9.5 lacs / year (Approximately)

Other failure components have separate distinct average failure times so replacing those components earlier will not save anything. On the contrary there will be loss of usage of the failure components. So Age Replacement Policy is suggested for critical failure components namely drag rope, spare link and O ring that have average age in the close vicinity.

V. RESULT & DISCUSSION

The Failure in any of the component of any subsystem can cause entire dragline to stop. The stoppage of dragline leads to heavy financial loss. The downtime of the machine needs to be minimized as for as possible to reduce financial losses. The mean time between failure clarify that the critical failure components drag rope, spare link and O ring of drag fails during relatively same period of time. Every time making system idle for replacement/ maintenance work will cause separate downtime cost. In spite of this spare link out of three components is stopped first for replacement/ maintenance work at 3.31hour. It is suggested to carry replacement/ maintenance work of drag rope and O ring within the same downtime of spare link that shall save individual requirement of downtime requirement and hence the cost.

VI. CONCLUSION

Preventive maintenance schedule has been suggested based on mean time between failure. Reliability improvement potential for subsystem drag and hoist is evaluated to be 40.65 % and 37.19% respectively. Age of the critical failure components is replaced keeping in view of minimizing downtime cost thereby giving saving potential. The critical failure components whose average age is in the close vicinity have been identified. Age replacement is suggested for the critical failure component whose operating life is in the close vicinity. Suggested preventive maintenance schedule leads to downtime saving potential of 9.5 lacs/year (approx).

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