

# Reliability Study of Surface Miner under different Geo-mining Conditions

Hemant Sharad Pande <sup>1</sup>, Dr. Manish D. Uttarwar <sup>2</sup>, Prof. M.S.Tiwari <sup>3</sup>

General Manager, Gevra OCP, SECL, India <sup>1</sup>

Professor (on Lien), Dept. of Mining, RCERT, Chandrapur, India <sup>2</sup>

Associate Professor, Ramdeobaba College of Engg & Management, India <sup>3</sup>

**ABSTRACT:** Now a day's Machines used in mining operations are capital intensive. The conventional shovel-dumper equipment system does not cope up the gigantic coal production and quality aspect. Surface mining technology is proved hallmark to minimize the multi dimensional activities in coal production along with mining of selective quality of coal. In India, presently there are approx 150 operating Surface Miners. Reliability of equipment and productivity of the coal parameters are handled with the appropriate use of surface mining technology. This technology is substituted by Shovel & Dumper technology where the surface miner equipment cost is low comparatively. Apart to this it has an advantage of mining the selected quality of coal, avoiding blasting and crushing. To meet techno-safe, economical and quality requirements this technology is useful. To make the mining technology cost effective it becomes essential to estimate absolute value of equipment reliabilities in corporate with geo mining parameter.

Despite of number of input resources, certain range and limitations, the capacity of GEVRA OCP is higher than the average yearly production. GEVRA OCP is been deployed by 10 numbers surface miners which minimized the exposure of risk in mining and used as a part of systematic method of production. The reliability analysis and prediction of one number of surface miner 2200 SM of Wirtgen (make) is studied in this paper. WEIBULL ANALYSIS is used for evaluating the reliability of the surface miner. Failure data of consequent three years is used in this method for analyzing the equipment reliability for its assemblies and sub-assemblies. Line fit plot acquired through Weibull analysis is the critical elements from reliability point of view. The plots acquired for different assemblies and sub assemblies are compared for evaluating the system for more probability of system failure. The effectiveness and performance of the equipment are evaluated by the result of this method of reliability. Deployment of more surface miners of different capacity and different make in different mega projects is the future scope so the reliability analysis of these equipments are to be studied.

**KEYWORDS:** Reliability, Weibull Analysis, Reliability Evaluation.

## I. INTRODUCTION

Reliability impact can be viewed on both the manpower management and economic aspect of the mining industry. High equipment reliability is a choice and not an accident of fortune.

Reliability analysis at operational stage is essential to verify the reliability of the same equipment for further deployment. TBF and TTF data is used for reliability analysis of mining equipment which are also useful to estimate the failure patterns. In this study the systems and subsystem of Surface miner is integrated to evaluates the actual equipment reliability.

A case study of one number of surface miner 2200 SM of Wirtgen (make) is presented in this paper to evaluate reliability as an early operating reliability. In this study the failure rate of machines is considered to evaluating reliability,

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### Gevra Opencast Mine – at a glance:

Gevra OCP is established in the year 1981 having an average stripping ratio of 1.3. The thickness range of four major coal seams are 117 -174 m and gradient degree from  $4^{\circ}$  to  $9^{\circ}$  at a depth of 160 -300 m. Surface miners are used for coal production while shovel-dumper combinations with large diametric deep hole drills are used for OB removal. The width and height of coal bench is 30 m and 10 m respectively with slope of  $60^{\circ}$  to  $75^{\circ}$ . The width of OB bench varies from 30 m to 35 m and height for 42 cum shovel is 20 mtr. The annual coal and OB production targets for the year 2014-2015 slated at 41 million tons and 49 million cubic meters respectively. It is expected to be the slated at a production target of 70 million tons in the coming 3 to 4 years. Gevra OCP possesses an array of mining equipments which are more complex and sophisticated warranting for increased capital costs. To meet the prevailing targets, the project thus demands not only for better but increased equipment reliability. Reliability is a good performance indicator of overall equipment condition.

### II. TECHNICAL SPECIFICATION OF WIRTGEN SURFACE MINER 2200 SM

In Gevra opencast mines there are approx of 10 surface miners deployed for production which are of different make but Wirtgen Surface Miner 2200 SM was considered in this study so as to obtain the better reliability study. The technical specifications are been mentioned below:



SPECIFICATIONS	
Working width	2.20 m
Max. cutting depth	0.35 m
Engine power	811 PS
Weight	51 t
Cutting drum drive	Mechanical
Number of crawlers	4
Travel drive	Hydraulic

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### III. CLASSIFICATION OF SURFACE MINER

Based on the action of cutting, the machine is classified as milling type, bucket wheel type and ranging-shearer-drum type. The position of the cutting drum is often decided based on the desired cutting capacity and compressive strength of rock.

Breakdown in the machine affects adversely on the production & productivity breakdowns of surface miners categorized in five major heads as given below:

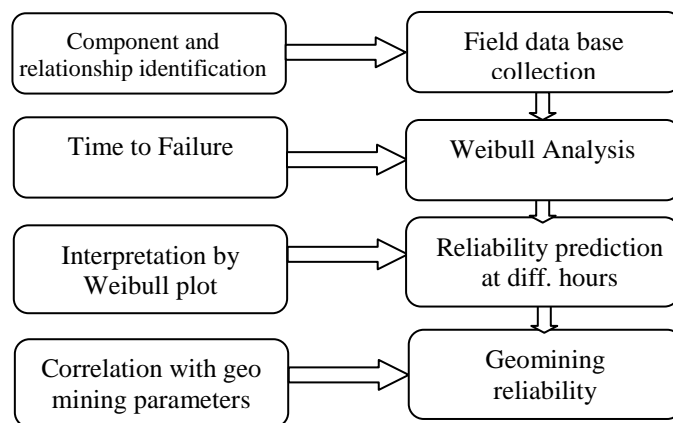
Mechanical & Electrical Breakdowns:

This type of breakdown include-

1. Steering related problem
2. Track related problem include track chain, Idler, Track gear box, roller etc.
3. Milling drum related problem including coupling, bearing, input adopter, shaft seal, shoe plate etc.
4. Lifting cylinder, guide column, lube & oil etc.
5. Electrical problem including emergency system, alternator, ac & other sensor related problem

### IV. METHODOLOGY

The evaluation of reliability of Surface miner is been studied in this paper and the methodology of the same is been developed.



The above eight steps flow chart is the case study of reliability evaluation of 2200 SM through Weibull analysis. The breakdown data of the machine has been acquired from the daily record data base of the component. From the OEM specifications and manuals, the specific life of the major assemblies and its sub-assemblies can be acquired. From the obtained results the probability of occurrence of error in data selecting for components failure, uncertainty is evaluated. Even a minor failure of the selected components leads to system failure and system operation breakdown and this is the case study of this research.

#### Reliability Data Types

TTR data, OEM generic data, field failure data etc. are some of the reliability data types which are available. The above data are been collected from the daily recorded data base. Some of the data like life of an assembly or sub-assembly or its components for very important parts can be obtained from the OEM specifications. Presence of shale band and Pebbly Intercalation can cause failure of machine dynamics

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## V. CASE STUDY

### Reliability

In mining technology, reliability of the equipment plays a vital role hence it is chosen by the experts working in mining industries. Using the reliability analysis technology the machine health can be monitored, component failure can be predicted before it fails, proper maintenance interval can be scheduled and cost of the maintenance also can be reduced. In reliability, economy and manpower management can be decided which is a major aspect in mining industry.

The 2200 SM surface miner is being focused in this paper. Weibull analysis is the method of reliability used for the calculation. Weibull analysis is a method for modeling data sets containing values greater than zero, such as failure data. In mining industry the data available like over all time to failure (TTF), it is much easier to go for a simple method to calculate reliability of the machines. The formula for reliability assuming a two parameter Weibull distribution is

$$R(x) = e^{-(x/\alpha)^\beta} ; \text{ for } x > 0 \quad (1)$$

Where “ $\beta$ ” is the shape parameter,  
“ $\alpha$ ” is the characteristic life  
“ $x$ ” is the time to failure.

The median rank is approximated by using Bernard's approximation using the formula

$$F(t) = (i-0.3)/(n+0.4) \quad (2)$$

Where “ $i$ ” is the corresponding rank of the data  
“ $n$ ” is the total number of samples

### Weibull Analysis

In this study, "Two parameter Weibull distributions" is used which is beneficial in forecasting the failure probability with extremely small samples and also to provide reasonable accurate failure analysis. Simple graphical line fit plots which are easier in understanding the failure characteristics of equipments can be obtained using this Weibull analysis. In the graph X axis represents the measure of life or operating time and Y axis represents the cumulative failure percentage. The two defining parameters of the Weibull line are the shape parameter  $\beta$ , and the characteristic life  $\alpha$ .

### Analysis Methodology

The Weibull distribution's strength is its versatility. Depending on the parameters' values, the Weibull distribution can approximate an exponential, a normal or a skewed distribution.

The theory behind a given analysis can often get results from excel that others might assume require specialized statistical software can be understood by an astute data analyst. The steps for performing weibull analysis are been listed below:

1. Create a new Microsoft excel sheet and in cell A1 give a label as “Break down Cycles”.
2. Enter the failure data of break down cycles into cells A2 to Ax (where “ $x$ ” is the number of break down cycles).
3. Select the cells A2 to Ax and select “Sort Ascending” option so as to arrange the data in lowest to highest format.
4. Select the cell B1 and give a label as “Rank”.
5. Type the integers 1 to  $x$  in the cells B2 through Bx.
6. Type “Median rank” in cell C1.
7. In cell C2 enter the formula “ $= ((B2-0.3)/(x+0.4))$ ”.
8. Copy cell C2 down through cell Cx in order to enter the same formula in cell C3 to Cx.
9. Label D1 as “ $1/(1-\text{Median Rank})$ ”.
10. Enter the formula “ $=1/(1-C2)$ ” in cell D2 and copy it down through Dx.

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11. Label "In (In (1/ (1-Median Rank)))" in cell E1.
12. Enter the formula "=LN (LN (D2))" in cell E2 and copy it down through Ex.
13. Label "In (Break down Cycles)" in cell F2.
14. Enter the formula "=LN (A2)" in cell F2 and copy it down through Fx.
15. Open data bar from menu bar and select data analysis.
16. From data analysis option highlight "Regression" option and then click "ok".
17. A pop up box asking to select some parameters arises.
18. Type "\$E\$1:\$E\$x" for "Input Y range" and "\$F\$1:\$F\$x" for "Input X range".
19. Select "labels" option by clicking on the checkbox beside it.
20. Select "New worksheet ply" by selecting the button beside it.
21. Select "line fit plots" by clicking the checkbox beside it.
22. A new excel sheet with some data and a graph is obtained.
23. Select the columns A to I and click on any of the column label in order to align the data.
24. Click once on the graph and stretch it as much as required for better view.
25. Type the label "Beta" in the cell A19.
26. Type the formula "=B18" in the cell B19.
27. Type the label "Alpha" in the cell A20.
28. Type the formula "=EXP(-B17/B18)"
29. Now copy the cells A19, A20, B19, B20 and paste in a new work sheet in the cell A1 by editing the cell selecting the "paste special" option and from that selecting the option "values".
30. Type the label "cycles" in the cell D1.
31. Type the cycle values in column D
32. Type the label "survival probability" in the cell E1.
33. Type the formula "=Weibull (D2,\$B\$1,\$B\$2, true)" in the cell E2.
34. Copy the cell E2 down through last.
35. Type the label "reliability" in cell F1.
36. Type the formula "=1-E2" in the cell F2.
37. Copy the cell F2 down through last.

### VI. OUTPUT OF WEIBULL ANALYSIS

Geo mining matrix for three years

Year	Avg Compressi ve strength	Avg Tensile strength	Avg shear strength	Avg density
2013-14	8.506428	0.6264285	1.519285 7	1.5271428
2014-15	17.31179	0.5064102	1.203846 1	1.4441025
2015-16	15.87638	0.7392161	0.948764 8	1.5271021

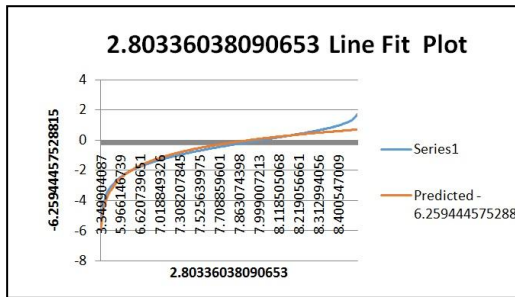
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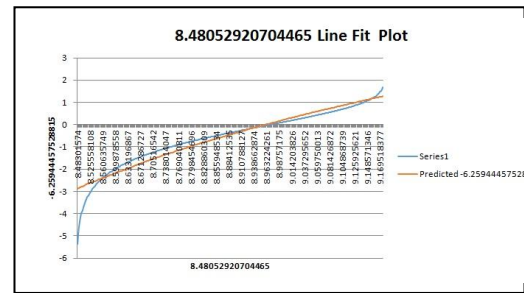
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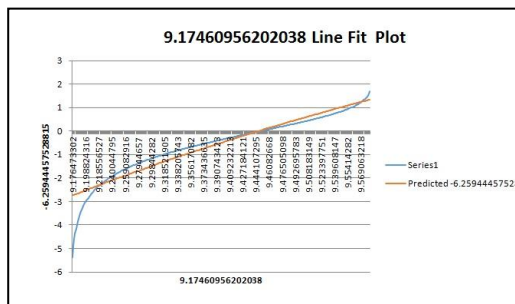
**Year -1 Overall Breakdown**



**Year -2 Overall Breakdown**



**Year -3 Overall Breakdown**



In the above graphs blue colored line represents the available reliability and the red line represents the predicted reliability. From the Graph of 1st year over all breakdown, it can be noticed that the predicted reliability for the 1st year follows almost same path during the total year except slightly increasing trend of actual reliability in the middle of year. During the final stage of the year actual reliability is follows same pattern while predicted reliability is in increasing trend .

From the 2nd Graph of Year 2 overall breakdown, it can be access that the predicted reliability in this year follows a straight line path throughout the year while actual reliability is lower at the initial phase of the year & after that follows increasing trend upto some extent till higher than predicted reliability. At the end of year actual reliability is slightly lower than predicted reliability and again boost up trend.

From the study of Year 3 overall breakdown graph it can be noticed that at some particular operating hours the predicted reliability line is lower compared to available reliability line which indicates that the reliability of the machine is much better than the predicted reliability. The main cause for this condition to occur is the scheduled maintenance and mini shutdown system which means the maintenance carried out at some particular interval of time.

## RELIABILITY OF SURFACE MINER BY WEIBULL ANALYSIS

Year	Year 1	Year 2	Year 3
CYCLE	Reliability	Reliability	Reliability
100	0.986068992	1	1
200	0.966491752	1	1
500	0.895663704	0.999999933	1
1000	0.765136741	0.999995674	1
2000	0.521856309	0.99972067	0.99999992

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5000	0.122132088	0.933311539	0.999918873
10000	0.006046543	0.011600464	0.913017417
20000	4.07665E-06	0	0
30000	8.73357E-10	0	0
40000	8.06022E-14	0	0
50000	0	0	0
60000	0	0	0

### **Geo-mining parameters of Gevra OCP**

The entire block of Gevra project is capped with thick coal bench. The general strike of the strata is NW-SE to E-W in major part of the block. Generally the dip direction is South and SW in the major part of the block.

The existence of three well defined coal seams has been proved and is named as lower Kusmunda, upper Kusmunda and E & F in ascending order [1].

The geo-mining parameters like compressive strength, tensile strength, shear strength etc. of coal material to be handled affecting equipment reliability.

In this case study, the average compressive strength of three consecutive years has been correlated with machine reliability.

From the obtained borehole logs, geological and litho-logical details were studied for the particular year. The average compressive strength of the coal for the selected year is computed and is depicted in the Table given below.

YEAR	AVG C.S	PRODUCTION
Year 1	8.50642857	3842800
Year 2	17.3117949	3867600
Year 3	15.8763895	3873200

The operating dimensions of face is almost same for all the three consecutive year of production.

### **Reliability Evaluation**

This section tabulates selected years of deployment of surface miner along with average compressive strength of coal material to be handled and associated reliability estimates. The Figures given below establish to correlate the two parameters, average compressive strength Vs Reliability of machines under consideration.

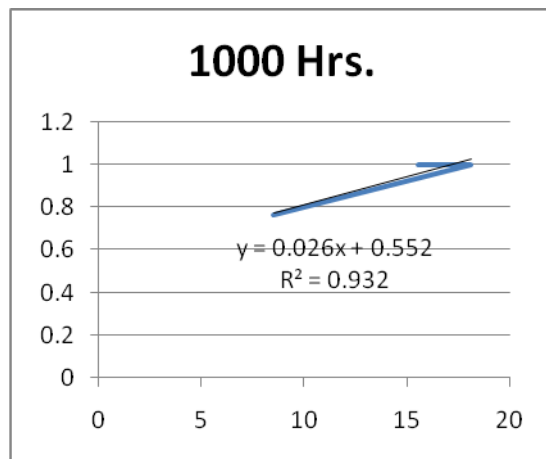
From the comparative analysis of the reliability graphical plots of the surface miners with the average compressive strength for selected three years, it can be primarily established that the reliability of the surface miners decreases after a certain initial hours of deployment with the increasing compressive strength of the coal material to be handled.

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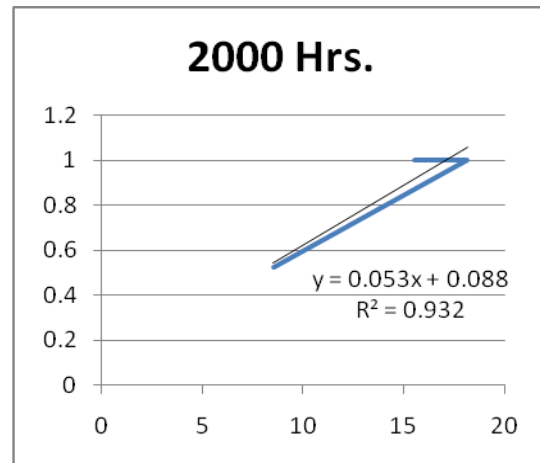
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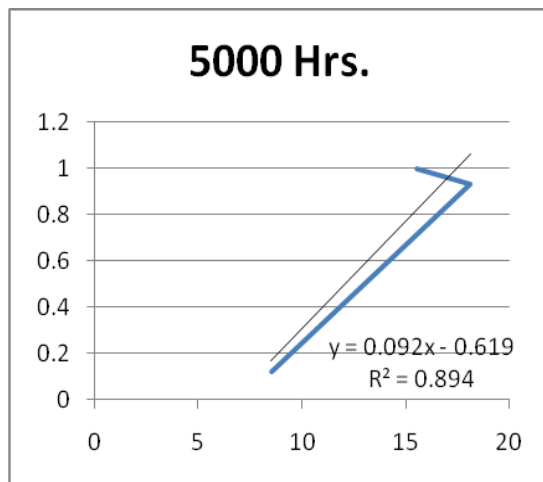
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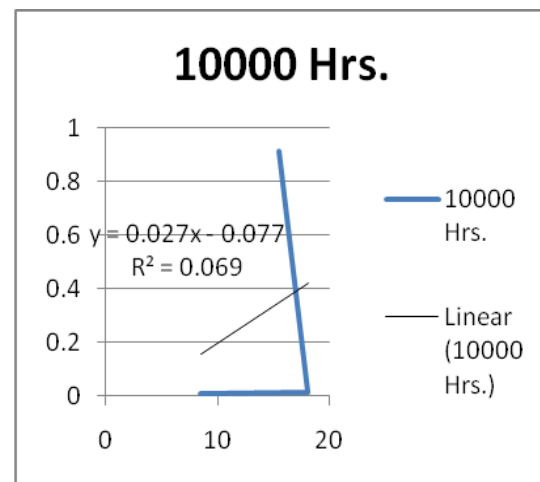
Compressive strength Vs Reliability at 1000 Hrs



Compressive strength Vs Reliability at 2000 Hrs



Compressive strength Vs Reliability at 5000 Hrs



Compressive strength Vs Reliability at 10000 Hrs

### OBSERVATIONS

During first 1000 hrs of operation, the reliability is to be linearly related with compressive strength. After attaining certain reliability, it is found to remain constant even though compressive strength decreases.

Similarly during 2000 hrs of operation, the reliability is to be linearly related with compressive strength. After attaining certain reliability, it is found to remain constant even though compressive strength decreases.

For 5000 hrs of operation, the reliability once again is found to increase with increase in compressive strength, however in a later stage, reliability is found to increase even if compressive strength decreases

During 10000 hrs of operation, the reliability is found to remain constant at lower levels but after certain increase in compressive strength, the reliability shoots up drastically.



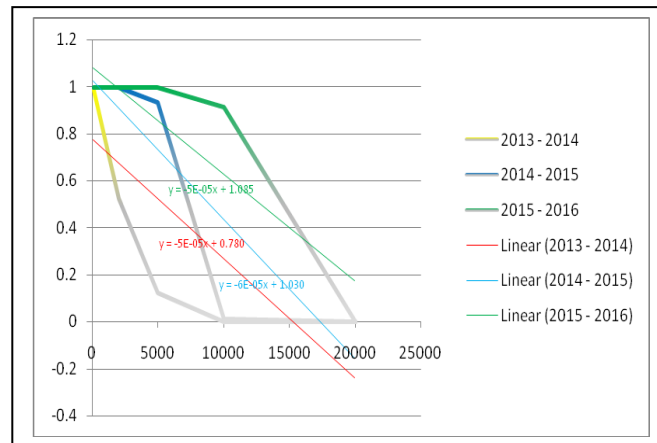
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## VII. CONCLUSIONS



In this paper, the analysis considers three years of surface miner operation for coal having varied characteristics and it was noticed that causes of breakdowns were a common. However it was observed that the frequency of electrical problem is higher warranting for review of the system from the point of view of original equipment manufacturer (OEM). It is most important to look into the preparedness for pro-active maintenance strategy to improve the Reliability of machine viz Surface miner.

The main aspect of this study is design of operational planning incorporating important operational parameters. By using Weibull analysis, the reliability under different geo-mining parameters was predicted and analyzed so and such that maintenance schedules can be planned to avert breakdowns. The study was aimed at improving the reliability of surface miner technology by identifying major threshold categories of breakdowns at different known geo-mining conditions. The study also focusses on possibility of few design changes from the OEM point of view.

## FUTURE SCOPE

- This type of study will be helpful for comparative reliability study of similar capacity and different make of machines.
- The Weibull 3 distribution parametric studies can be done for some cases for which the  $\beta$  value is greater than 6.0.

## ACKNOWLEDGEMENT

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