IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 10, Issue 2 (Nov. - Dec. 2013), PP 47-52
www.iosrjournals.org

A Comparative Reliability Analysis of Bulldozers arriving at workshop in Eastern India: A Case Study.

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ABSTRACT : *Study of reliabilities of machinery used in any kind of production is of utmost necessity for optimum use of man power and resources to make the process cost effective and with minimum downtime. This is applicable for all large and small industries alike. But in small industries data is not accurately stored and it becomes difficult to estimate product reliabilities. This paper focuses on a case study to estimate the reliabilities of two competing machines, when the only available data is Time To Failure. The Weibull Parameters are calculated using Microsoft Excel 2010. The results show that after knowing the reliabilities of both the Bulldozers at different lengths of time, we can ascertain which of them is preferable to use at which time period.*
Keywords :*Characteristic Life, Reliability, Shape parameter, Time To Failure, Weibull Distribution,*

I. Introduction

Product Reliabilities have always been of utmost interest in any industry. But when it comes to obtaining the reliabilities of two or more products used in the same industry for the very same purpose, its impact can be viewed on both the manpower management and economic aspect of the firm. This paper addresses the reliability of Bulldozers which come for Survey off Grounding at a workshop in Eastern India. Bulldozers are the one of the most widely used mining machines used to move large quantity of materials.

Reliability analysis helps us to ascertain maintenance intervals [1], and with correct decision making, maybe even increase the length of the intervals and thus decrease maintenance costs. This has fueled many studies to be performed in the field of reliability analysis of mining equipment [2-7]. In the inspiring work of Barabady, J; 2005 [7], the Time between Failures (TBF) data was used and it was possible to estimate the failure patterns and hence decision making regarding timed and economic scheduling of maintenance activities. Again in [1] the authors continued their work beautifully to include the TBF and Time to Repair (TTR) data to perform an elaborate case study and hence calculate the reliability and availability characteristics.

However in an industry or firm where data are not systematically stored but only some raw uncensored data like overall Time To Failure (TTF) is available it is much easier to go for a simple method to calculate reliability of the competing machines(in this case, two Bulldozers- Type-I and Type-II). The main objectives of this paper are-

- To calculate the Weibull Parameters- Shape Parameter β , Characteristic Life α ; and interpret the results with the corresponding Bathtub Curves. Thus a complete Weibull analysis.
- To estimate the reliabilities of the Type-I and Type-II Bulldozers and compare these at the end of different time intervals.

II. Approach and Methodology

The formula for Reliability assuming a Two Parameter Weibull Distribution is

$$R(x) = e^{\left(-\left(\frac{x}{\alpha}\right)^{\beta}\right)}$$

where $\beta$is the Shape Parameter,α is the Characteristic Life and $x$is the Time to Failure

The most important process is the analysis and computation of collected data. We calculate the Median Rank and the transformed median rank and so on. By performing a simple linear regression we can obtain parameter estimates that will help us to infer the reliabilities of the concerned machinery; and thus are able to compare them.

III. Case Study

We calculate and compare the reliabilities after different time intervals of the two main types of Bulldozers arriving at the workshop. The Bulldozers, Type-I&Type-II are used in various mine fields for movement of large quantities of materials. The Bulldozers that have been considered in this paper have been previously been remade (repaired) at the workshop before being sent to the mine field. Since not much systematized and well stored data was to be found, the TTF of 10 Bulldozers, from the 1st quarter of 2013, each of Type-I and Type-IIare considered, each having the same characteristics- a) Workshop remade and b) not usable any longer.

Similar considerations have been applied and similar characteristics have been considered while treating the data of Dumpers as well. The beauty of this wonderfully detailed method by William M. Dorner [8], is that it is very simple and easy to compute, and most importantly it gives a fair idea of the product reliabilities at the end.

3.1 Data Collection

The different failure data of Bulldozers were collected for a period of three months (January, February and March) and ten of them have been considered amongst the ones which were Workshop remade and brought for Survey off Grounding, to maintain uniformity and soundness in this study.

Table-1 *TTF of Type-I andType-II Bulldozers*

Serial No.	Type-I No. of Hours Run	Type-II No. of Hours Run
1	15811	7895
2	2294	11534
3	16564	4035
4	19120	7402
5	13900	6887
6	30	2986
7	13925	685
8	1110	487
9	4575	5975
10	15400	5002

3.2 Data Analysis

3.2.1 Data Preparation and Computation

Two basic steps have been performed-

- We have prepared a different table for each of CAT and KOM Bulldozers, and arranged the data in ascending order, ranking them in the process.
- The median ranks are then approximated using Bernard's Approximation: -

$$F(t)=\frac{i-0.3}{n+0.4}$$

where 'i' is thecorresponding rank of the data and 'n' is the total number of samples (in this case 10).

Some corresponding values which are calculated using the median rank are tabulated alongside.

Table-2 Type-I

Type-I No. Of Hours Run	Rank	Median Rank	1/(1-Median Rank)	ln(ln(1/(1-Median Rank)))	ln(No. Of Hours Run)
30	1	0.067	1.072	-2.663	3.401
1110	2	0.163	1.195	-1.723	7.012
2294	3	0.259	1.350	-1.202	7.738
4575	4	0.355	1.552	-0.821	8.428
13900	5	0.451	1.824	-0.508	9.539
13925	6	0.548	2.212	-0.230	9.541
15400	7	0.644	2.810	0.032	9.642
15811	8	0.740	3.851	0.299	9.668
16564	9	0.836	6.117	0.593	9.714
19120	10	0.932	14.857	0.992	9.858

Table-3 Type-II

Type-II No. Of Hours Run	Rank	Median Rank	1/(1-Median Rank)	ln(ln(1/(1-Median Rank)))	ln(No. Of Hours Run)
487	1	0.067	1.072	-2.663	6.188
685	2	0.163	1.195	-1.723	6.529
2986	3	0.259	1.350	-1.202	8.001
4035	4	0.355	1.552	-0.821	8.302
5002	5	0.451	1.824	-0.508	8.517
5975	6	0.548	2.212	-0.230	8.695
6887	7	0.644	2.810	0.032	8.837
7402	8	0.740	3.851	0.299	8.909
7895	9	0.836	6.117	0.593	8.973
11534	10	0.932	14.857	0.992	9.353

3.2.2 Estimating the Weibull Parameters and Fitting a line to the data

As previously stated we will be using a Two-Parameter Weibull Distribution to calculate the required reliabilities. Using the Regression function in Microsoft Excel software, the values are examined and the Weibull Parameters are estimated. We also plot a graph between ln(No. Of Hours) versus Transformed Median for both sets of data and the slope of the graph directly gives us the Shape Parameter.

Table-4

SUMMARY OUTPUT	Type I							
Regression Statistics								
Multiple R	0.913							
R Square	0.834							
Adjusted R Square	0.813							
Standard Error	0.481							
Observations	10							
ANOVA								
	df	SS	MS	F	Significance F			
Regression	1	9.338	9.338	40.358	0.0002			
Residual	8	1.851	0.231					
Total	9	11.189						
	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	-4.774	0.686	-6.957	0.0001	-6.356	-3.191	-6.356	-3.191
ln(No. Of Hours Run)	0.502	0.079	6.352	0.0002	0.3203	0.685	0.320	0.685
$\beta =$	0.502							
$\alpha=$	13290.47							

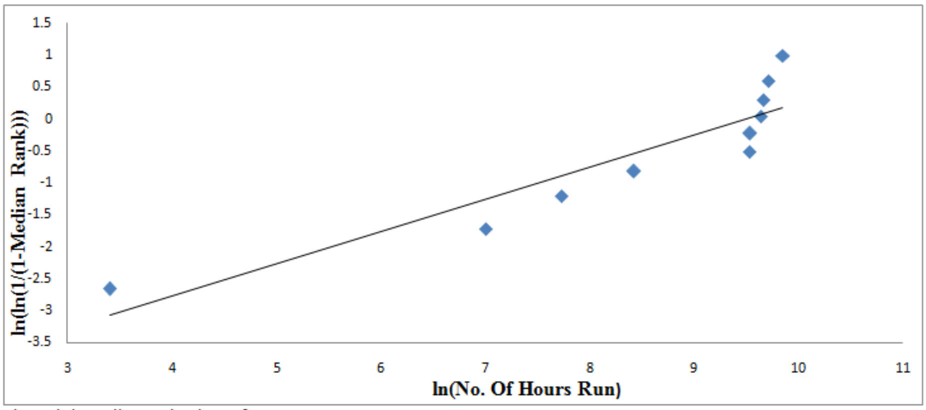

Fig.1 Fitting a line to the data of Type-I

Table-5

SUMMARY OUTPUT	Type II							
Regression Statistics								
Multiple R	0.953							
R Square	0.908							
Adjusted R Square	0.897							
Standard Error	0.357							
Observations	10							
ANOVA								
	df	SS	MS	F	Significance F			
Regression	1	10.168	10.168	79.619	1.97E-05			
Residual	8	1.021	0.127					
Total	9	11.189						
	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	-8.796	0.934	-9.417	0.00011	-6.642	-6.642	-10.951	-6.642
ln(No. Of Hours Run)	1.005	0.112	8.922	0.000219933	1.265	1.265	0.745	1.265
β =	1.005							
α=	6318.88							

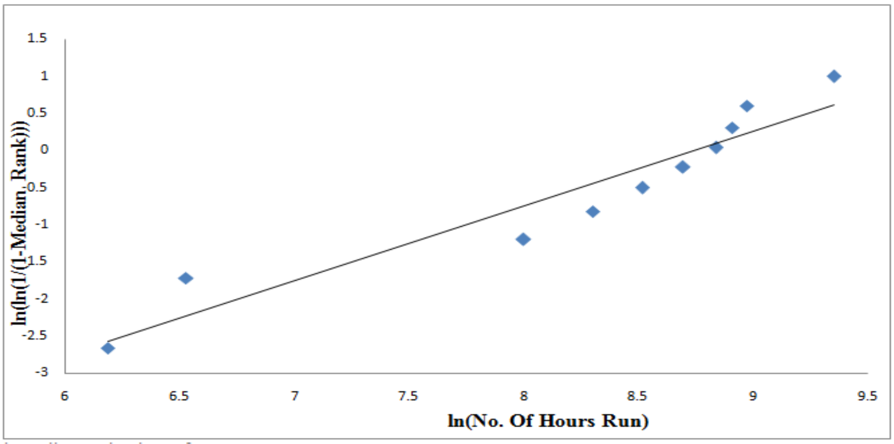

Fig.2 Fitting a line to the data of Type-II

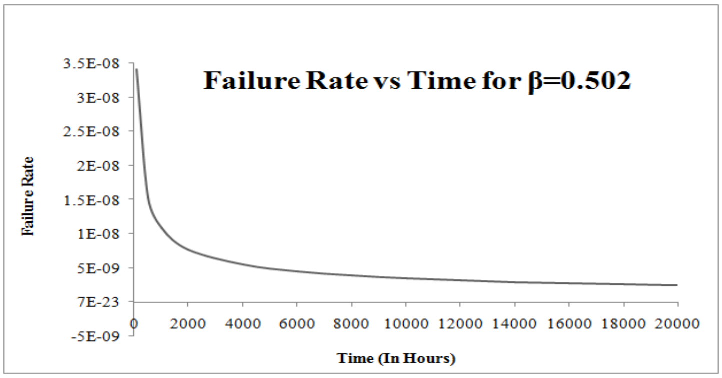

Fig. 3 Graph for Failure Rate vs Time for Type-I Bulldozer(Infant Mortality Rate)

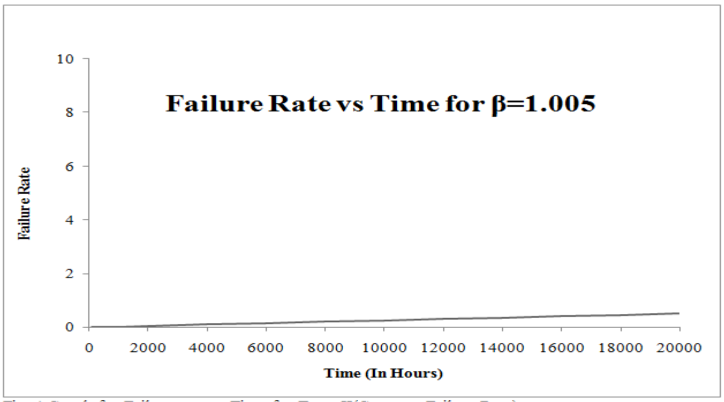

Fig. 4 Graph for Failure rate vs Time for Type-II(Constant Failure Rate)

We have computed β(Shape Parameter) and α(Characteristic Life) for both sets of data. The corresponding failure rates are also plotted against time.

IV. Results and Discussion

The reliabilities of the Bulldozers and Dumpers are calculated and a graph is plotted between them to give us a comparative overview among each of their types.

Table-6 Reliability Comparisons

No. Of Hours	Type-I	Type-II
0	1.00	1.00
1000	0.76	0.85
2000	0.68	0.73
3000	0.62	0.62
4000	0.58	0.53
5000	0.54	0.45
6000	0.51	0.39
7000	0.48	0.33
8000	0.46	0.28
9000	0.44	0.24
10000	0.42	0.20
11000	0.40	0.17
12000	0.39	0.15
13000	0.37	0.13
14000	0.36	0.11
15000	0.35	0.09
16000	0.33	0.08
17000	0.32	0.07
18000	0.31	0.06
19000	0.30	0.05
20000	0.29	0.04
21000	0.28	0.04
22000	0.28	0.03
23000	0.27	0.03
24000	0.26	0.02
25000	0.25	0.02
26000	0.25	0.02
27000	0.24	0.01
28000	0.23	0.01
29000	0.23	0.00
30000	0.22	0.00

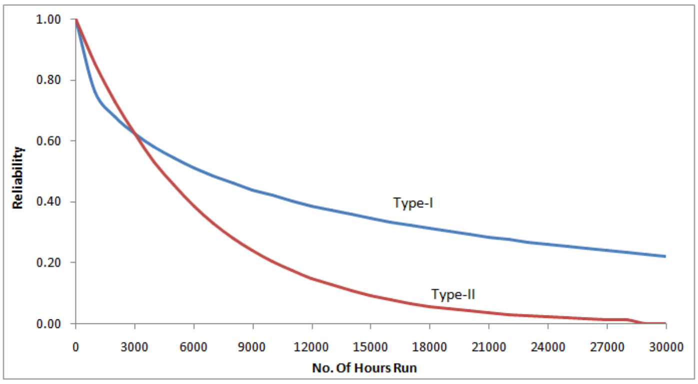

Fig. 5- Graph showing the reliability comparisons of Bulldozers

We have calculated the values of Shape Parameter (β) and Characteristic Life (α) for both the Type-I and Type-II Bulldozers.

β< 1 gives us a fair idea that most of the products in question has a decreasing failure rate. It is safe to say that the *Type-I Bulldozers* fail during its 'Burn-In' period.

β> 1 indicates failure rate increases as time passes by. Since the value is only slightly greater than 1 (1.005 to be precise) the increase in failure rate is very slow for the *Type-II Bulldozers*. In fact one can say the failure rate is almost constant.

α = 13290.47 indicates that about 37% of the *Type-I Bulldozers* will survive at least 13290.47 hours.
α = 6318.88 indicates that about 37% of the *Type-II Bulldozers* will survive at least 6318.88 hours.

The results shown in Table-6 as well as in Fig. 5 give us a clear of the reliabilities of the two types of Bulldozers. At less than 3000 hours Type-II Bulldozers have a greater reliability but after 3000 hours it is quite clear that the Type-I Bulldozers have a greater reliability.

V. Conclusion

From this study one can observe that that even when there is very little data to work with, we can still get a measure of the reliability of any equipment This case study shows that between the Type-I and Type-II Bulldozers, the former one is to be preferred when usage is more than 3000 hours, while the later one is to be preferred when expected usage is less than 3000 hours. We can definitively conclude that equipment reliability can be properly stated only with respect to its time of usage. This will help us decrease the number of breakdowns significantly.

It is often seen that that the Time To Failure data that fits a Weibull Distribution also fits a lognormal distribution [9]. Thus there is further scope of using a Lognormal Distribution in reliability analysis and comparing it with Weibull Distribution based on this type of data. Further we can also go for a availability and maintainability analysis.

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