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RELIABILITY ANALYSIS OF A FLEET OF LOADERS IN SANGAN IRON MINE

ANALIZA NIEZAWODNOŚCI SYSTEMU ŁADOWAREK W KOPALNI ŻELAZA SANGAN

As the size and complexity of open pit mining equipment continue to increase, the implications of equipment failure become ever more critical. Unplanned equipment failures and their consequences have significant influence on the total operating cost of a mining system. Keeping this in view, a reliability study has been performed for a fleet of loaders in Sangan iron mine of Iran. In this study, two approaches were considered for analyze maintenance data, namely a basic maintenance approach and a reliability based approach. In this paper, trend and serial correlation test were used to validate the assumption of independent and identically distribution. K-S test was carried out with the aid of Easy-Fit software to select best fit distribution. Finally, reliability the loaders 560 No. 1, 560 No. 2 and 4400 for the next 50 hours of operation have been predicted, 5.1×10^{-3}, 8.3×10^{-3} and 1.2×10^{-4}, respectively. To achieving the high reliability a review on maintenance program must be performed.

Keyword: Reliability analysis, Maintenance, Failure data, Probability distribution, Sangan iron mine

Wraz ze wzrostem skali i złożoności sprzętu używanego w górnictwie odkrywkowym, konsekwencje awarii sprzętu stają się coraz bardziej dotkliwe. Nieplanowane awarie sprzętu i ich skutki w znaczący sposób wpływają na całkowite koszty operacyjne systemu górniczego. Mając to na uwadze, przeprowadzono studium niezawodnościowe dla floty ładowarek w Irańskiej kopalni żelaza Sangan. Rozważano dwa podejścia do analizy danych serwisowych, to znaczy podstawowe podejście serwisowe i podejście niezawodnościowe. Aby zweryfikować założenie niezależnej i identycznej dystrybucji w pracy zastosowano testy korelacyjne trendu i serii. Aby wybrać najlepiej pasującą dystrybucję, przy pomocy oprogramowania Easy-Fit przeprowadzony został test K-S. Prognozowano niezawodność ładowarek 560 No. 1, 560 No. 2 i 4400 w ciągu następnych 50 godzin działania – odpowiednio 5.1×10^{-3}, 8.3×10^{-3} i 1.2×10^{-4}. Aby osiągnąć wysoki poziom niezawodności, należy przeprowadzić przegląd programu serwisowania.

Słowa kluczowe: analiza niezawodnościowa, konserwacja, dane serwisowe, rozkład prawdopodobieństwa, kopalnia żelaza Sangan

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1. Introduction

Reliability studies are an important part of any equipment maintenance management program. In the mining industry, reliability investigations are becoming a standard practice, as the equipment become more complicated and the effective use of resources is critical for achieving higher productivity (Vagenas et al., 1997). Failures of capital intensive equipment and their consequences have a strong impact on production costs. Since failure cannot be prevented entirely, it is important to minimize both its probability of occurrence and the impact of failures when they do occur. Therefore, an effective maintenance program is a must (Barabady & Kumar, 2008). The effectiveness of a maintenance program for a piece of equipment depends on the knowledge about the reliability and maintainability characteristics of the machine components. In addition, some of the factors that influence the effectiveness of maintenance are human error, the design of equipment and the operating environment.

In order to effectively analyze maintenance data of mining equipment, two approaches can be considered, namely a basic maintenance approach and a reliability based approach. The basic maintenance approach utilizes graphical methods to analyze failure trends in equipment, thus providing an indication of excess repair times or frequency. Other parameters that can be determined include Availability, Mean Time between Failures (MTBF) and Mean Time to Repair (MTTR). The reliability based approach uses a graphical and statistical methodology to fit theoretical probability distributions to the collected maintenance data for prediction of future failure trends. This approach provides insight information about replacement times and the effectiveness of current management polices (Nuziale & Vagenas, 2000; Vagenas et al., 2003).

Many studies since the middle 1980s to now performed on reliability and maintainability mining equipment. Kumar and et al. (1989) performed a reliability investigation for a fleet of diesel operated LHD machines in Swedish mine. In this paper, analytical methods like Kolmogorov-Smirnov test and maximum likelihood estimation was used in the analysis. Kumar and Klefsjö (1992) presented a reliability analysis of hydraulic systems of LHD machines using the power law process model (PLP), a certain form of non homogeneous Poisson process. Performance evaluation of a prototype automatic Load-Haul-Dump operating in Zinkgruvan mine was studied by Kumar and Vagenas (1993). Vagenas et al. (1994) performed an analysis of maintenance data of a fleet of Caterpillar trucks deployed at the Aitik open pit mine in northern Sweden. Reliability of diesel powered LHD in underground Quebec mine during an 18 month period was analyzed by Paraszczak and Perreault (1994). Vagenas et al. (1997) offers a step by step methodology to conduct maintenance analysis from a basic study of failure trends in equipment to a reliability based evaluation. Software architecture for reliability of mining equipment was investigated by Nuziale and Vagenas (2000). This paper discusses the design and development of PC software architecture (RelSoft) for basic maintenance evaluation and reliability analysis. Maintainability and reliability analysis of a fleet of shovels were performed by Roy et al. (2001). Vagenas et al. (2003) demonstrated how an approach using a maintenance methodology can be applied to assess the reliability of underground mining excavation. Hall and Daneshmend (2003) proposed summarize relevant techniques for reliability analysis and identify data requirements and information sources. The reliability, availability and maintainability of a LHD with failure and repair data by Markov modeling were studied by Samanta et al. (2004). Barabady and Kumar (2008) presented a reliability and maintainability analysis of the crushing plant at Jajarm Bauxite mine in Iran. In this paper an attempt has been made to analyzed reliability of three loaders over time period 12 months in Sangan iron mine of Iran.

2. Basic Concepts

The following definitions are applied to better understanding of basic concepts and also to facilitate the discussion of reliability analysis in this paper.

1. Failure: The termination of the ability of an item to perform a required function.
2. Mean Time Between Failures (MTBF): The mean time of the failure distribution of a machine or component. For a constant failure rate it is expressed as the total operating time divided by the total number of repairs.
3. Mean Time To Repair (MTTR): The mean time required to repair a component, expressed as the total repair time divided by the total number of repairs.
4. Availability: The percentage of time that a system is operating satisfactorily. It is represented by the following equation.

$$\text{Availability} = \frac{MTBF}{MTBF + MTTR} \tag{1}$$

5. Percentage of Total Repairs: The percentage of total repairs, expressed as the repair frequency of a system divided by total repair frequency for all systems.
6. Reliability: The probability that a system or component will operate without failure under a given condition for a specified time period.

$$R(t) = 1 - F(t) \tag{2}$$

Where $R(t)$ is the reliability function evaluated at time t in hours and $F(t)$ is the cumulative failure distribution function.

7. Reliability of a system in series: A system comprised of components, which must all, be operating in order for the system to operate. The reliability of a series system is defined as:

$$R_s(t) = \prod_{i=1}^{n} R_i(t) \tag{3}$$

8. Reliability of a system in parallel: A system comprised of components, which operate independently of each other. The reliability of a parallel system is defined as:

$$R_p(t) = 1 - \prod_{i=1}^{n} \left(1 - R_i(t)\right) \tag{4}$$

3. Application of maintenance and reliability analysis in Sangan iron mine

3.1. Sangan iron mine location

The field study was carried out in Sangan iron mine in 16 km north of Sangan and 300 km southeast of Mashhad, Iran (Fig. 1). Geographically, it is located at 60°16′ longitude and 34°24′ latitude. Sangan deposit is a magnetite skarn type. In this area, mineralization is mainly associated with a specific intrusive rock formed in Oligo-Miocene. The total geological reserve of the Sangan iron ore mine is estimated 1.2 billion tons, approximately. The Sangan iron mine is under development and the mineral processing plant is designed to produce 2.6 million tons of iron pellets per year in phase one of the project (Esmaeili, 2011).

Fig. 1. Location of Sangan iron mine (Safari et al., 2010)

3.2. Data collection and classification

First step in reliability analysis is data collection. In order to perform an effective maintenance analysis, accurate and complete data is essential (Vagenas et al., 1997). The maintenance data presented in this paper relates to three loaders (560 No. 1 and 560 No. 2) Hepco and (4400) International. These data collected over a time period of 12 months (from April 2006 to April 2007) by using hand written forms prepared by maintenance personal, daily report and maintenance cards. These maintenance cards include time to failure, the machine hour meter and the time to repairs. Before analyzing the machine's characteristics and failure data, the machine must be classified into a number of systems and subsystems in order to categorize the types of failure occurring on the machine. These classifications will depend on the maintenance records kept by maintenance personnel, as well as the reasoning describing these records (Vagenas et al., 2003). In this paper preventive maintenance is applied as a subsystem in order to ensure a proper maintenance. Preventive maintenance defined as the actions performed in attempt to retain an item in a specified condition by providing systematic inspection, detection and prevention of incipient failure (Oyebisi, 2000; Paraszczak & Perreault, 1994). Useful classification subsystem for a fleet of three loaders was presented in Table 1.

TABLE 1

Useful classification subsystem for loaders

Subsystem	Code
1. Engine	ENG
2. Electrical	ELEC
3. Hydraulic	HYD
4. Preventive maintenance	PM
5. Bucket	BUK
6. Braking	BRK
7. Structural	STR
8. Transmission	TRAN
9. Tire	TR

3.3. A basic maintenance analysis using graphical methods

Once the data has been classified into different subsystems, the next step was analyzed data by graphical methods in order to evaluate parameter such as repair frequency, time between failures (TBF), time to repair (TTR), total working hours and total repair time. The part of the data collected for loader 560 No. 1 are given in Appendix, Table A. Some times more than one subsystem has been repaired. In these cases, for the purpose of this study, the failure reason was assigned only to those subsystems for which machine were stopped. For example, for the failure number one, the subsystems engine and transmission were repaired, but engine will be assigned as reason failure and transmission will be treated as censored failure. Based on this, the TBFs and TTRs for subsystems are calculated. Repair frequency, total repair time, percent of total repairs, minimum and maximum for each type of failure for three loaders provides in Table 2. The data from Table 2 may be better visualized in figs 2 and 3. Fig. 2 displays the percent of total repairs and repair frequency versus type of failure. By studying Fig. 2, it can be seen that the engine

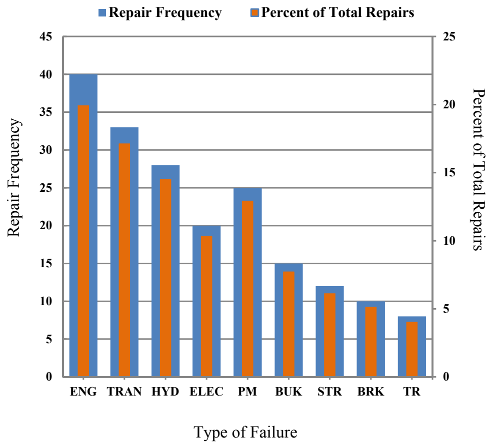

Fig. 2. Repair frequency and percent of total repairs versus type of failure

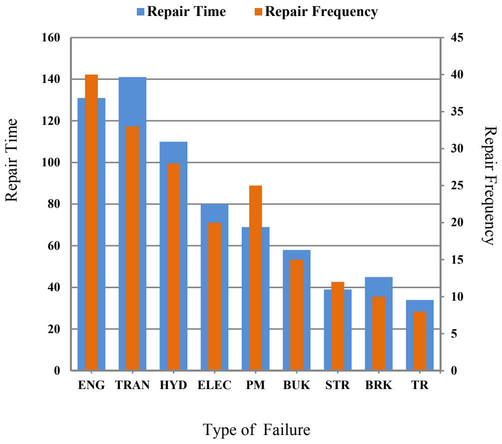

Fig. 3. Repair time and repair frequency versus type of failure

and transmission are the most frequently occurring repairs to loader 560 No. 1 and consume the most repair time. Fig. 3 has been provided a plot of repair frequency and repair time versus type of failure. These graphs provide a better view of failure trends of equipments. A summary of the operating time, total number of repairs, and total repair hours for three loaders provides in Table 3. In this table availability is calculated by Equation 1.

TABLE 2

An overall view of the maintenance characteristics for each type of failure

Type of failure		ENG	TRAN	HYD	PM	ELEC	BUK	STR	BRK	TR
	RF*	40	33	28	25	20	15	12	10	8
	RT	131	142	111	69	80	58	40	45	34
	PTR	20	17.2	14.6	13	10.4	7.8	6.2	5.2	4.1
Loader 560 No. 1	Min	0.4	0.5	0.6	0.5	0.5	1	1	0.7	1
	Max	19.5	25.3	15	10.6	14	16	9	8.5	12
	Avg	3.2	4.3	3.9	2.7	4	3.8	3.3	4.5	4.2
	RF	23	17	46	30	11	9	6	4	4
	RT	91.3	73.9	155.6	105.1	69.2	50.5	31.8	17.1	29.5
	PTR	15.3	11.3	30.6	20	7.3	6	4	2.6	2.6
Loader 560 No. 2	Min	0.3	0.4	0.5	0.5	0.5	0.5	1	0.8	1
	Max	15	16.7	28.2	11.2	21	12	7.8	6.3	18.5
	Avg	3.9	4.3	3.3	3.5	6.2	5.6	5.3	4.2	7.3
	RF	35	22	31	22	15	12	10	7	6
	RT	124.4	83	108.9	51.8	57.6	42.5	36.5	28.2	25.1
	PTR	21.8	13.7	19.3	13.7	9.3	7.5	6.2	4.3	3.7
Loader 4400	Min	0.5	0.4	0.5	0.5	0.6	1	0.5	0.2	1.1
	Max	28	18	16.6	9.4	10	13	12	10	8
	Avg	3.5	3.7	3.5	2.3	3.8	3.5	3.6	4	4.1

* RF = Repair Frequency, RT = Total Repair Time (Hours), PTR = Percentage of Total Repairs (%), Min = Minimum Repair Time (Hours), Max = Maximum Repair Time (Hours), Avg = Average Repair Time (Hours)

TABLE 3

The summary of failure characteristics of a fleet of three loaders over time period 12 months

	Loader 560 No. 1	Loader 560 No. 2	Loader 4400
Operating Hours	1857	1670	1588
Total Number of Repairs	191	150	160
Total Repair Hours	710	624	558
MTTR (Hours)	3.7	4.1	3.4
MTBF (Hours)	9.7	11.1	9.9
Availability	72%	72%	74%
Fleet Availability (Average of availability of three loaders)	73%		

3.4. Reliability based analysis

3.4.1. Verification of assumption IID

The verification of the assumption that the failures are Independent and Identically Distributed (IID) is critical. If the assumption that the data is independent is not valid, then classical statistical techniques for reliability analysis may not be appropriate (Law & Kelton, 1991). Sample independence means that the data are free of trends and each failure is independent of the preceding or succeeding failure. Identically distributed data mean that all the data in the sample are obtained from the same probability distribution (Roy et al., 2001; Vagenas et al., 1997).

Two common graphical methods used for assessing sample independence are the trend test and the serial correlation test. The trend test can be used to determine trends in the failure patterns of an entire machine, or an individual subsystem. A trend test involves plotting the cumulative failure number against the cumulative time between failures. The presence of a trend indicates correlation (Law & Kelton, 1991). The shape of the trend plot will reveal if a piece of equipment is experiencing a decreasing failure rate (improving) or an increasing failure rate (deteriorating). A linear plot indicates that there is no observable trend in the failure rate. An increase in the failure rate is depicted by a trend line with a constantly increasing slope, whereas a decrease in the failure rate is illustrated by a trend line with a constantly decreasing slope (Vagenas et al., 1997). Fig. 4 illustrates the trend test for loader 560 No. 1. As can be seen in Fig. 4, trend test shows a straight line and it means that the data is free of trend. This test was performed for the other two loaders and the same result was obtained. Therefore, the first criterion for independent and identically distributed data is satisfied.

The serial correlation test is a plot of the data pairs (X_i, X_{i-1}) for $i = 1, \ldots, n$, where n is the failure number. If the X's are independent, then the points should be scattered randomly on the diagram. If the X's are dependant or correlated, the points should lie along a line. It is important to note that the data points should be plotted in the order that they were collected. A scatter plot of the time between failures (TBF) for loader 560 No. 1 is displayed in Fig. 5. It shows that the points are scattered randomly throughout the plot. This indicates that the data is free of cor-

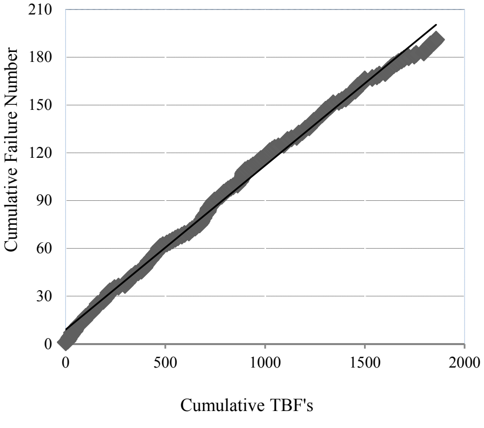

Fig. 4. A plot for test the presence of trend

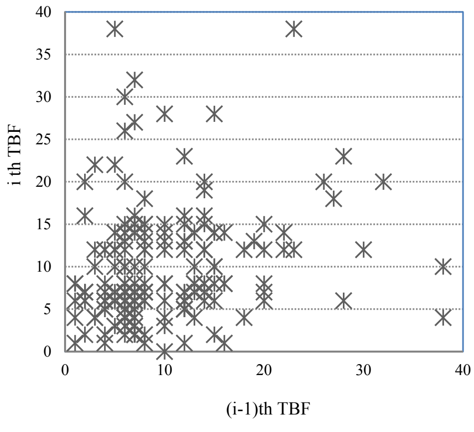

Fig. 5. Scatter plot for test serial correlation

relations and can be assumed to be independent. Scatter plots for loader 560 No. 2 and loader 4400 indicate similar trends. Thus, we can accept the assumption of independent and identically distributed (IID) data for all three loaders and consequently the data can be fitted to theoretical probability distributions for reliability calculations.

3.4.2. Assess the goodness-of-fit of a theoretical probability distribution to the data

Once the data has been collected and found to be free of correlations and trends, then the next step is to assess the goodness-of-fit of a probability distribution model to the failures. Theoretical probability distributions offer the benefit of smoothing out any irregularities in the data collected and contribute to unbiased decisions about a process or system (Roy et al., 2001). Several type of probability distribution methods were applied to analysis of failure data (Appendix, Table B). The two most common methods for assessing the goodness-of-fit of a data set are the Chi-Squared test and the Kolmogorov-Smirnov (K-S) test (Law & Kelton, 1991; Miller et al. 1990). One of the most widely used non parametric test for assessing the goodness-of-fit of repair times and time between failures is the Kolmogorov-Smirnov (K-S) test (Kumar & Vagenas, 1993; Paraszczak & Perreault, 1994). The K-S test examines for differences between the theoretical distribution and the observed cumulative distribution. This test can easily be performed using a probability distribution fitting software package. The data for the loader 560 No. 1 was tested for goodness-of-fit. Five distribution methods such as Weibull 2 parameter, Weibull 3 parameter, Exponential 1 parameter, Exponential 2 parameter and Lognormal were fitted to the time between failures (TBF) data. Table 4 illustrates the results of these tests for the TBF data using the Easy-Fit software. This software assesses the goodness-of-fit of a probability distribution to the data using theoretical probability distributions.

The values under the K-S test indicate the maximum deviation between the cumulative distribution of the data and the theoretical probability distribution of the TBF model for each loader subsystem and for the entire machine. For the K-S test, the best values are the lowest calculated for each of the five theoretical probability distributions.

TABLE 4

Goodness of fit for determination of best fit distribution for the TBF data of loader 560 No. 1

	K-S test (goodness-of-fit)					**Best fit**	**Parameters**
Sub-system	**Weibull 2 parameter**	**Log-normal**	**Exponential 2 parameter**	**Weibull 3 parameter**	**Exponential 1 parameter**		
1	**2**	**3**	**4**	**5**	**6**	7	**8**
ENG	0.12184	0.1696	0.15877	0.13223	0.16248	Weibull 2 parameter	$\alpha = 1.3728$ $\beta = 50.329$
TRAN	0.10891	0.0916	0.10882	0.07565	0.16934	Weibull 3 parameter	$\alpha = 1.1974$ $\beta = 45.975$ $\gamma = 5.5725$
HYD	0.18526	0.1327	0.24449	0.16054	0.21913	Lognormal	$\sigma = 1.1788$ $\mu = 3.4199$
PM	0.15351	0.1443	0.11908	0.13356	0.17043	Exponential 2 parameter	$\lambda = 0.01905$ $\gamma = 6.0$

1	2	3	4	5	6	7	8
ELEC	0.12197	0.1522	0.12701	0.17538	0.12258	Weibull 2 parameter	$\alpha = 0.9916$ $\beta = 61.952$
BUK	0.2122	0.2264	0.35456	0.14736	0.31877	Weibull 3 parameter	$\alpha = 0.46325$ $\beta = 98.101$ $\gamma = 6.0$
STR	0.16167	0.18109	0.19227	0.18577	0.15969	Weibull 2 parameter	$\alpha = 1.0057$ $\beta = 118.05$
BRK	0.14008	0.12233	0.22343	0.12871	0.2219	Lognormal	$\sigma = 1.5044$ $\mu = 4.6454$
TR	0.18238	0.21914	0.22363	0.20604	0.23514	Weibull 2 parameter	$\alpha = 1.6302$ $\beta = 214.09$
Machine	0.1245	0.1192	0.24681	0.1245	0.24681	Lognormal	$\sigma = 0.68788$ $\mu = 2.1463$

3.4.3. Reliability estimation

The next step after determination of the best fit distribution is estimate reliability of the entire machine and their subsystems using the reliability function of the fitted distribution (Equation 2). Table 5 displays the results of reliability estimation for the next 50 hours of operation of each subsystem of loader 560 No. 1. The reliability of each loader as a whole unit may be calculated in two ways:

1. Using Equations (3) and (4) to determine the reliability of the machine based on its system design configuration.
2. Using a probability distribution fitted to the failure data of the entire machine.

Using Equations (3) and (4) the reliability of the machine can be estimated based on the reliability of its components (Miller et al., 1990; Kumar & Granholm, 1988). Using this method, the machine is considered to be comprised of a system in series and in parallel and the reliability each subsystem is used to determine the overall reliability of the machine. However, in this case, it is necessary to know the design configuration and the machine's system architecture. This information is usually considered as property of the equipment manufacturer. Another method for calculating the reliability of a machine is to fit a probability distribution to the failure data of the entire machine (Vagenas et al., 1977). In this study, the reliability of the all three loaders was calculated based on the latter method for the next 50 hours of operation (Table 6).

TABLE 5

Reliability estimation of subsystems of loader 560 No.1

Subsystem	**ENG**	**TRAN**	**HYD**	**PM**	**ELEC**	**BUK**	**STR**	**BRK**	**TR**
Reliability estimation (50 hours)	0.37	0.38	0.33	0.43	0.45	0.5	0.67	0.68	0.91

TABLE 6

Reliability estimation for each of three loaders in the next 50 hours of operation

Loaders	Best fit	Parameter	Reliability estimate (50 Hours)
Loader 560 No. 1	Lognormal 2 parameter	$\sigma = 0.6878$ $\mu = 2.1463$	5.1×10^{-3}
Loader 560 No. 2	Lognormal 2 parameter	$\sigma = 0.7919$ $\mu = 2.0145$	8.3×10^{-3}
Loader 4400	Weibull 2 parameter	$\alpha = 1.648$ $\beta = 13.039$	1.2×10^{-4}

4. Conclusions

Maintenance and reliability studies should be an integral part of mine engineering management for the effective utilization of resources and for achieving higher productivity. In this paper, the case study shows that the engine and transmission in the loader 560 No. 1, the hydraulic in the loader 560 No. 2, the engine and hydraulic in loader 4400 are the most frequency occurring repairs and consume the most repair times. These subsystems are critical from a reliability point of view. The Weibull and Lognormal distribution provided the best fit distribution, in the most cases, to the time between failures data of three loaders. Then, reliability loaders 560 No. 1, 560 No. 2 and 4400 for the next 50 hours of operation have been predicted, 5.1×10^{-3}, 8.3×10^{-3} and 1.2×10^{-4}, respectively. The reason of low reliability of loaders can be expressed closed to end of working life. To achieving the high reliability a review on maintenance program must be performed. This study was made to assist engineers in Sangan iron mine to identify the critical and sensitive subsystems in the loader fleet for better maintenance planning, leading to enhanced equipment availability, reduced maintenance and production costs.

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APPENDIX

TABLE A

A part of failure data for reliability based analysis of loader 560 No. 1

No.	**Systems repaired**	**TTR (hours)**	**Cumulative TTR**	**TBF (hours)**	**Cumulative TBF**
1	**2**	**3**	**4**	**5**	**6**
1	ENG-TRAN	3	323.3	5	734
2	TRANS	2	325.3	6	740
3	ENG	2	327.3	6	746
4	TRAN	1	328.3	15	761
5	HYD-PM	3	331.3	8	769
6	ENG-BUK	2	333.3	13	782
7	STR	3	336.3	6	788
8	ENG-ELEC	4	340.3	5	793

1	**2**	**3**	**4**	**5**	**6**
9	ENG	5.7	346	12	805
10	TRAN-TR	3	349	10	815
11	TR	4	353	13	828
12	ELEC	2	355	12	840
13	BUK	3	358	22	862
14	HYD	6	364	3	865
15	BUK	5	369	10	875
16	PM	2	371	3	878
17	HYD	4	375	6	884
18	ELEC-BUK	7	382	4	888
19	TRAN-TR-HYD	7	389	1	889
20	ENG-PM	4	393	1	890
21	HYD	2	395	4	894
22	HYD-TRAN	2	397	6	900
23	HYD	1	398	14	914
24	BRK-TRAN	6	404	15	929
25	STR-ENG	9	413	10	939

TABLE B

Probability distribution models for analysis of failure data (Zacks, 1992)

Distribution	**Density function**	**Distribution function**
Weibull 2 parameter	$f(x)=\frac{\alpha}{\beta}(\frac{x}{\beta})^{\alpha-1}\exp\left(-(\frac{x}{\beta})^{\alpha}\right)$	$F(x)=1-\exp\left(-(\frac{x}{\beta})^{\alpha}\right)$
Weibull 3 parameter	$f(x)=\frac{\alpha}{\beta}(\frac{x-\gamma}{\beta})^{\alpha-1}\exp\left(-(\frac{x-\gamma}{\beta})^{\alpha}\right)$	$F(x)=1-\exp\left(-(\frac{x-\gamma}{\beta})^{\alpha}\right)$
Exponential 2 parameter	$f(x)=\lambda\exp\left(-\lambda(x-\gamma)\right)$	$F(x)=1-\exp\left(-\lambda(x-\gamma)\right)$
Lognormal 2 parameter	$f(x)=\frac{\exp\left(-\frac{1}{2}\left(\frac{\ln x-\mu}{\sigma}\right)^{2}\right)}{x\sigma\sqrt{2\pi}}$	$F(x)=\Phi\left(\frac{\ln x-\mu}{\sigma}\right)$
Exponential 1 parameter	$f(x)=\lambda\exp(-\lambda x)$	$F(x)=1-\exp(-\lambda x)$

In Weibull (α: shape parameter ($\alpha > 0$), β: scale parameter ($\beta > 0$), γ: location parameter ($\gamma = 0$ yeilds two parameter Weibull distribution)).

In Exponential (λ: inverse scale parameter ($\lambda > 0$), γ: location parameter ($\gamma = 0$ yeilds one parameter Exponential distribution)).