Reliability and maintainability analysis of universal drill machine at Saoner mines, Nagpur, India

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Abstract. Mining is the extraction of coal and minerals from the earth crust. Mining is mainly divided into two categories: opencast and underground mining. These mining activities are accomplished with the help of heavy engineering machine. The execution of these mining machines depends on machine reliability, operating environment, operating process and skill of the operator. In mining, a large number of heavy machinery are used and those are very costly. The failure of these machinery effects coal production. Therefore to overcome these losses, reliability analysis is required. This paper represents a case study showing reliability and maintainability of universal drill machine (UDM) at Saoner mines, Nagpur, India. UDM is a crucial mechanism for the mining industry. The main work carried out by these machines is drilling operation at a minimum time with higher accuracy resulting in the increased productivity. For survival in the intense competition and complicated environmental condition, it is necessary that UDM must be maintained effectively and efficiently. To check whether the collected data are independent and identically distributed (IID) or not, trend and serial correlation test are performed. To get the best fit distribution of data by K-S test, the easy-fit software is used. These distributions draw reliability as well as maintainability graph of the system. These graphs show that the machine is not working properly. To achieve high reliability of UDM, proper review of maintenance programme should be done.

Key Words: Universal drill machine; identically distributed; operating environment

1. Introduction

Now a day in the mining industry, reliability and maintainability analysis has become an essential technique for getting the optimum utilization of the resources [1-2]. Failure of any equipment of mining has a strong impact on production costs. Machines are not ideal thus failure of the machines is inevitable. Failures can’t be eliminated completely but it can be reduced to a greater extent by the effective maintenance techniques [3]. These techniques are effective when the maintenance cost is lower. The cost is one of the major parts of the total production cost of the industry that varies from industry to industry. A large number of failure in the industry is due to the unplanned maintenance process. To prevent this, a proper maintenance process should be followed by i.e preventive maintenance [4]. Preventive maintenance is periodic maintenance of equipment so that it can run effectively and efficiently.

For the analysis of mining data in an effective way, reliability based approach has been considered. This technique takes into consideration a statistical method for the fitment of the probability distribution of the data. This distribution reflects the upcoming trends of the failures. It enables to find insight information about replacement time and maintenance time [5]. Many studies since the middle 1980s to now performed on reliability and maintainability of mining equipment. In this paper, an analytical method like Kolmogorov-Smirnov (K-S) test is performed.

In this paper, an attempt has been made to analyze the reliability of UDM over a time period of 44 months in western coal field limited, Saoner mines no.3.

2. Study procedure
For reliability and maintainability analysis of UDM machines step-by-step procedure has been followed that is represented in ‘Figure 1’

![Diagram](Image)

**Figure 1.** Procedure of estimation of reliability and maintainability.
2.1. UDM Machine
Universal drill machine (UDM) is important equipment for the mechanization of the drilling operation. UDM mainly used for fast drilling and bolting of roof. UDM is designed for underground mining for drilling in 360 degrees. It can move in a two-way direction. It has a maximum penetration speed so that it can perform its drilling operation in a minimum time and with maximum productivity. It has an overall length of 8240 mm, ground clearance 220 mm, track center 1755 mm, track shoes width 330 mm, gross machine weight 9500 kg, electric motor power is 65 hp.

![Universal drill machine (UDM)](image)

2.2. Data Collection
In this paper data collected over a period of 44 months (From July 2014 to June 2018 ) by using excel sheet prepared by maintenance personnel, daily report and maintenance cards. These maintenance cards include machine working hour, failure time and repair time. In order to perform an effective maintenance analysis accurate and complete data is essential [6]. In this paper, reliability analysis of EIMCONELECON -052 machine has been done.

2.3. Reliability based analysis
Data are sorted in chronological order and checking is done for any trend or correlation of the data. If there is no presence of any trend or correlation it can be considered as independent and identically distributed (IID) data[7]. IID states that data belong to the same probability distribution [8].

There are two graphical methods that are used in this paper for the evaluation of the independence of the sample i.e. Trend test and Serial correlation test.

2.3.1. Trend test
The failures trends of the UDM are determined with the help of trend test. This test comprises to plot the graph between cumulative failure number against the cumulative time between failure and cumulative time to repair [9]. Graph pattern decided the nature of the data, the straight line shows no trend, and increasing slope shows a positive failure rate and decreasing slope negative failure rate [10]. ‘Figure 5’ illustrates the trend test of TTR and ‘Figure 6’ illustrate the trend test of TBF. As seen in the figure that the trend test shows a straight line and it means that data is free of trend.
2.3.2. Serial Correlation test
The serial correlation test is a plot of the data pairs between \( X_i \) and \( X_{i-1} \) for \( i = 1, \ldots, n \), whereas \( n \) is the failure number. The scatterplot shows data are independent and line plot shows data are dependent. A scatter plot of the time between failures (TBF) and time to repair (TTR) of UDM has been shown in ‘Figure 7’ and ‘Figure 8’ respectively. This graph shows that points are scattered randomly throughout the plot. This indicates that the data is free of correlations and can be assumed to be independent.

Thus, from the above technique, it can accept that the assumption of independent and identically distributed (IID) data is valid. Due to this data can be fitted to theoretical probability distributions for reliability calculations.

2.4. Determining best-fit theoretical probability distribution
As no trend and correlation are identified in data, then the next step is to assess the goodness-of-fit of probability distribution model of the failures. Several types of probability distribution methods can be used for failure data among them two most common method for assessing the goodness-of-fit of data set are the chi-squared test and the Kolmogorov-Smirnov (K-S) test [11-13]. In the paper, we had done K-S test to find the best fit distribution. This test can be easily performed using Easy-fit software. Seven distribution method such as exponential, exponential 2P, lognormal, lognormal 3P, normal, weibull, weibull 3P. We fitted to the time between failure (TBF) and time to repair (TTR)
data. Table 1 and Table 2 illustrate the result of these test for the TBF and TTR data using the Easy-fit software.

**Table 1.** Goodness of fit for determination of best-fit distribution for the TBF data of UDM machine

| Distribution | Value | Rank | Parameters |
|--------------|-------|------|------------|
| Exponential  | 0.3958 | 7 | $\lambda=0.00442$ |
| Exponential (2p) | 0.2008 | 6 | $\lambda=0.00891$ |
| Lognormal    | 0.0812 | 4 | $\sigma=0.31107 \mu=5.3747$ |
| Lognormal (3p) | 0.0750 | 2 | $\sigma=0.19199 \mu=5.852 \gamma=-128.12$ |
| Normal       | 0.0765 | 3 | $\mu=226.23$ |
| Weibull      | 0.0851 | 5 | $\alpha=3.7714 \beta=245.94 \gamma=99.863$ |
| Weibull (3p) | 0.0719 | 1 | $\alpha=1.919 \beta=142.2 \gamma=99.863$ |

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

3. Result

3.1. Reliability estimation

The next step after determination of the best fit distribution is to determine the reliability of the machine. From Table 1 and Table 2, it is depicted that weibull 3p has the lowest value for both TBF and TTR by K-S test, thus weibull 3p distribution is used. Reliability estimation of UDM has been made for different time intervals as shown in table 3. It is clearly seen that reliability decreases with time. The results are shown graphically in ‘Figure 7’.
3.2 Maintainability estimation
MTTR of the UDM has been calculated from the data that has been collected. The estimation of the maintainability of the UDM has been made for a different time interval as shown in Table 4. It has been clearly shown that maintainability increases as the time interval increases. The result is shown graphically in ‘Figure 8’.

Table 4. Maintainability at different time interval

| Time (hr.) | Maintainability |
|------------|-----------------|
| 0          | 0               |
| 20         | 0.329436        |
| 50         | 0.63786         |
| 80         | 0.79781         |
| 100        | 0.873483        |
| 120        | 0.909084        |
| 150        | 0.950077        |
| 240        | 0.991734        |
4. Conclusion

For the economic sustainability of machine during mining activities require high reliability. Therefore, reliability and maintainability have become the main concern of mines manager. In this study data of UDM of Saoner mines, Nagpur has been analyzed for reliability and Maintainability purposes. This study shows that main problem of low reliability is overheating of the machine that causes many parts to fail like motor, hydraulic pump. All hydraulic apparatuses rubber item may damage, oil itself degrade after reaching 82ºC temperature and losses its property, due to this wear and tear of hydraulic spares will also increase. To achieve high reliability a review on maintenance program must be performed. This study identified the critical and sensitive part of UDM that causes the overheating problem for better maintenance planning, leading to enhanced equipment availability, reduced maintenance and production cost.

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