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Reliability analysis of percussive rotary drill bits in consideration with their failure modes

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ABSTRACT

Efficient drilling is essential in rock drilling for the overall production. Drilling bits are the consumable elements in drilling process and their working hours in the field is important with respect economy. The reliability study of drilling bits is important as it indicates the overall effective production. The present study estimates the reliability of percussive drill bits based on failure hours. This study also study the best fit Regression model against the failure hours. The relevant data pertaining to this study has been collected from Granite mine. The outcome of this study is helpful to understand the different failure modes of drill bits and their bit life assessment with consideration of Compressive strength

KEYWORDS: *Percussive Drill bits, Compressive strength, Bit failure mode, Drill bit life, Regression model, Anova Approach*

I. INTRODUCTION

Percussive rotary drilling is the most common drilling method is used for hard rock exploration and also for drilling blast holes. The drill consists of a bit (steel crown) with cemented carbide inserts. The dimensions of the steel crown varies with application and rock properties [1]. The Wear of WC (tungsten carbide) and cobalt (co) compositions used in the inserts of a drill bits is surveyed by Larsen-Basse.J. They addressed that the relationship between drilling variables and wear and the influence of structure and composition of the tungsten carbide-cobalt sintered alloy drill bits on their wear-resistance [2]. The new view and the understanding grates can hopefully be utilized for making better selections of cemented carbide grades based on local wear conditions and also for future development of new WC/Co grades, better adapted to the complex conditions of rock drilling. Liang et al. Through a detail analysis of the mechanical failures in the drilling rig encountered during construction in hard formations, key parts of the rotary drilling rig work rig were improved and improved, including the design of the removable compound drive. The test results show that the improved percussive rotary drilling rig's construction efficiency and life are clearly increased [4]. The UCS of the rock is closely correlated with the bit life. The insert failure in percussive rotary drill bits is found to dominate the complete failure of the bit [5].The present research presents the various modes of failure of percussive rotary drill bits in the Granite mine by the comprehensive study of the drill bit life time in the field, this study also determines the reliability of percussive rotary drill bits.

1.1 FAILURE MODES OF DRILL BITS

During drilling with percussive rotary drill machine the drill bit effected due to the following mechanical properties of the rock are hardness, strength, abrasiveness, structure of rock etc. the drill bit may tend fail in various modes, those are

a) Button failure due to large radial force
b) Twisted breakage failure
c) Failure due to corrosion
d) Buttons failure due to incorrect attachment with drill

e) Failure due to worn out of crank body

Fig-1 Various Failure modes of drill bits

II. DATA COLLECTION

The study conducted over a period of 2 weeks to determine the drill bits life time and the data collected from the log books in records room of the mines and its failed drill bit in store room. By consulting field personnel of the mine and got sufficient data for this work. The collected data was interpreted in Regression model.

In this research work the drill bit data including life of drill bit, reasons for bit failure have been collected from the two adjacent granite mines situated in Andhra Pradesh. The collection of reliable data is always a challenge task. Thus in this study the drill bits life and various failures identified are collected with respect of working benches. The data collected from two adjacent granite mines of RL Puram of Cheemakurthy village which are located on the state highway SH 53 leading to Kanigiri from Ongole and is about 20 kilometres from Ongole town which is well connected by all-weather Road from Chennai and Hyderabad and is well connected by Train from Chennai. Mines are extended from East Longitude 79°50’16” and North latitude 15°35’08”and latitude 15°34'52" N to 15° 35' 3"N and Longitude 79°49'8"E to 79°49'26"E.

Fig 2 Testing of compressive strength of a granite sample using Schmidt hammer

Compressive strength of the rock is taken by using the Schmidt hammer which gives Reynolds number. By using the Schmidt hammer the compressive strength of granite rock tested in the sample collected in different benches. The Fig 2 shows the testing of compressive strength using Schmidt hammer in different samples collected from different benches.

The data collected from the mining location is given in Table 1.

Table 1: - List of drill bit life data in different benches

Sl. no	Type of drill bit	Drill bit number	Drill bit life in hours	Drilling depth in feet	Compressive strength	Reason of failure bit	Location of bit failure	Rock type	Bench number
1	Button bit	RH10F6115J48	24	590	120.65	High hardness of strata	Ore Bench	Granite	13
2	Button bit	RH115M40124	24.3	600	121.32	Mechanical wear and tear of buttons	Waste rock	Granite	13
3	Button bit	SG246J929045	24	595	119.33	Mechanical wear and tear of buttons	Ore bench	Granite	15
4	Button bit	RV274k81068	26	620	122.56	High hardness of strata	Ore bench	Granite	16
5	Button bit	RS015N55355	21	550	115.42	Presence of joints in rock	Ore bench	Granite	17
6	Button bit	RV017J07960	25	650	124.84	Mechanical wear and tear of buttons	Waste rock bench	Granite	20
7	Button bit	DG017L32293	26.8	660	135.57	High hardness of strata	Ore bench	Granite	21
8	Button bit	FJ812H38580	28	690	129.15	Mechanical wear and tear of buttons	Ore bench	Granite	23
9	Button bit	RM017T23550	22	580	120.2	High hardness of strata	Ore bench	Granite	24
10	Button bit	SK017V96329	25	625	122.4	Mechanical wear and tear of buttons	Ore bench	Granite	25
11	Button bit	PK906E60996	25.2	635	130.31	Mechanical wear and tear of buttons	Ore bench	Granite	26
12	Button bit	RH017H94326	24.6	620	123.99	High hardness of strata	Ore bench	Granite	29

III. RESULTS AND DISCUSSIONS

3. 1 Determination of Correlation of matrix

A correlation matrix is simply a table displaying the correlation coefficients for various variables. A matrix displays the correlation between every possible pair of values in a table. It is a powerful tool for summarizing large datasets, identifying and visualizing patterns in the data. A correlation matrix consists of rows and columns representing variables. Each cell in the table contains a correlation coefficient. Table 2 represents the correlation coefficients for the three variables considered in this study.

Table 2 Correlation between the drill bit life, Drilling depth and Compressive strength

	Drill bit life in hours	*Drilling Depth in feet*	*Compressive strength (MPa)*
Drill bit life in hours	1		
Drilling Depth in feet	0.91591659	1	
Compressive strength (MPa)	0.79222657	0.81580575	1

A correlation matrix table showing the correlation coefficient between different sets variables such as drill bit life in hours, drilling depth in feet's, compressive strength. The correlation matrix shows the positive values. The coefficient value is <1 is perfectly positive linear correlation and the coeffient value is =0 there is no linear correlation. From Table-2 it is observed that, the correlation between drill bit life hours and drilling depth in feet is highest as compared to other combinations. It also indicates that the life of drill bit greatly affected by drilling depth. The correlation matrix also suggests that the correlation between drill bit hours and compressive strength is high. The matrix shown in Table-2 also indicated some correlation between drilling depth and compressive strength, which should be verified by statistical method as logically there is no relation.

The figure 3 shows for regression analysis by taking the drilling depth in X-axis and drill bit life in hours in Y-axis. The linear equation obtained by the plotting the data in X-axis and Y-axis. The drill bit life data points were fitted against the best fit line by using a regression analysis. The goodness of fit value R^2 is 0.8389. The obtained results in the form of goodness of fit value also verify that the three were a good correlation between the two variables.

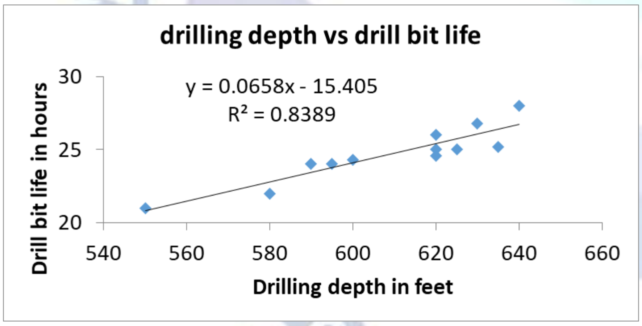

Fig-3 Graph (drilling depth VS drill bit life)

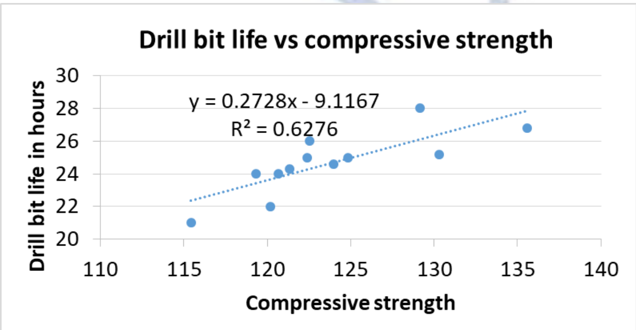

Fig-4 Graph (Compressive Strength VS drill bit life)

The figure 4 shows for regression analysis by taking the compressive strength in X-axis and drill bit life in hours in Y-axis. The linear equation obtained by the plotting the data in X-axis and Y-axis. The drill bit life data points were fitted against the best fit line by using a regression analysis. The goodness of fit value R^2 is 0.6276. The obtained results in the form of goodness of fit value also verify that there were a moderate correlation between the two variables.

3.2 ANOVA approach

One-way analysis of variance ("ANOVA") compares the means of two or more independent groups to determine if there is statistical evidence that the associated population means are significantly different. The one-way ANOVA is a parametric test. This test is also known as: One-Factor ANOVA, single factor.

One-way ANOVA is typically used to investigate the single independent variables or parameters. If any variations, or different levels of that factor have a measurable effect on a dependent variable

ANOVA is helpful for testing three or more variables. However, it results in fewer errors and is appropriate for a range of issues. ANOVA groups differences by comparing the means of each group and includes spreading out the variance into diverse sources.

3.3 Data normalization

The data shown in Table-1 have variability in their scale value. This variability will lead to incorrect or biased results in the study. Further to get the reliable results a normalization technique must be applied. The advantage of normalization technique is that it will reduce the error and will also help to determine the accurate results. The below Table-3 represents that normalized value of each variable in this study.

Table 3 Normalized value for Drill bit hours, Drilling depth and Compressive strength

Drill bit life in hours	Drilling Depth in feet (Actual)	Compressive strength (MPa)
0.43	0.44	0.26
0.47	0.56	0.29
0.43	0.5	0.19
0.71	0.78	0.35
0	0	0
0.57	0.78	0.47
0.83	0.89	1
1	1	0.68
0.14	0.33	0.24
0.57	0.83	0.25
0.6	0.94	0.74
0.51	0.78	0.43

Table-4 ANOVA one way analysis

Anova: Single Factor

SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
Drill bit life in hours	12	6.26	0.5216	0.073415		
Drilling Depth in feet's (Actual)	12	7.83	0.6525	0.086075		
Compressive strength (MPa)	12	4.9	0.40833	0.076852		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.358316667	2	0.17915	2.274144	0.11878	3.284918
Within Groups	2.599758333	33	0.07878			
Total	2.958075	35				

The table 4 represents ANOVA Analysis for the data the Probability P= 0.119. Here the P value clearly shows that there is more statistical significant difference between the mean of three parameters because it greater than 0.05. It represents that there is direct relation between the compressive strength and drilling depth.

IV. CONCLUSION

Data is collected to investigate three key parameters at the drilling site to find the cause of drill bit failure in granite rock. Failure data collection was conducted for three specific types of failures: PRD drill bit failure due to high forming hardness, mechanical damage to the liner including loss of teeth and buttons, failure due to manufacturing defects and other factors, and failures due to compressive strength of rock.The data collection considers three other parameters as well as the failure mode.

Consider the life of the drill bit (in hours), the depth of the hole (in feet), and the compressive strength of the rock (When using a Schmidt hammer). The most appropriate Regression model for the data set was determined and the corresponding probability function was derived. The reliability of PRD bits was evaluated using an ANOVA approach showing acceptable results. In this study, a drill bit failure analysis was presented to understand the conditions of rotary percussion drilling and identify the factors that cause these failures.

The importance of this study will help engineers to understand different types of PRD drill bit failures in granite mines. It also helps evaluate the reliability of PRD drill bits in a specific location. Failure reasons can be used to upgrade PRD drill bits. This study will help determine the operators for improving penetration rates, reducing drilling costs and extending the life of PRD drill bits.

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