

STATISTICAL MODELLING OF DRILL BITS DULL

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ABSTRACT. Drill bits are probably the most important component of the drilling process. They are the vanguard part in the well depth progression and, thus, drill bit choice is a major factor for successful and emergency-free operations. In this research, five major drilling parameters are observed for a period of 5+6 years and for different types of drill bits (a total of 22 bits) drilling in different lithological and technical working conditions: nominal OD [D, m]; total drilling meters [ΣM]; total working hours [Σh]; average WOB [T, t] and average RPM [min^{-1}]. Bit dull grading is affected by one unregulated parameter: drilled rock formations. This suggests for a certain error in the statistical model since the formations cannot be chosen or changed. Using STATGRAPHICS software, experimental models are brought out showing the connection between bit dull grading and the other drilling parameters.

Key words: drill bits, statistics data, statistical modelling, dull grade.

СТАТИСТИЧЕСКО МОДЕЛИРАНЕ НА ОТРАБОТВАНЕТО НА КАЛОРАЗРУШАВАЩИ ИНСТРУМЕНТИ

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РЕЗЮМЕ. Скало-разрушаващите инструменти са може би най-важният компонент на сондажния процес. Те са средството, осъществяващо разрушаването на скалата на забоя и, в този смисъл, изборът им е основен фактор за успешна и безаварийна работа. В настоящето изследване, за период от 5+6 години, е документирана работата на пет основни параметъра на различни типове длета (общо 22 бр.) при различни геоложки и технически условия на работа: номинален външен диаметър [D,m]; сумарни просондирани метри [ΣM]; натрупани часове работа [Σh]; усреднен осев товар [T, t] и усреднена честота на въртене RPM [min^{-1}]. Отработката на длетата се влияе от параметър, неподлежащ на регулиране – просондираните скални формации. Това предполага известна неточност в статистическия модел, тъй като последните не могат да се избират или променят. Чрез статистически софтуер STATGRAPHICS са изведени експериментални модели за връзката между износването длетата и другите сондажни параметри.

Ключови думи: длета, статистически данни, статистическо моделиране, отработка.

Introduction

Drill bits are the most important part of the drilling process. They are the vanguard part in the well depth progression. Choosing a suitable bit based on the conditions downhole is a major factor for successful and non-emergency operations.

This study represents drill, bit wear and its specific characteristics. Based on a collected data, an experimental statistical model is calculated. Its goal is to clarify factors, affecting drill bits working process, any suggestions on improvement measures, and last but not least and if possible, well price reduction.

The drill bit dull grading criteria were unified and imported in practice by the International Association of Drilling Contractors (IADC) in the 1980s. They are valid for both roller cone and fixed-cutter bits (PDC – poly diamond crystalline), providing all the information on the active elements, bearing parts, outer gauge diameter, any damage, and reasons for pulling the bit out of hole (Rabia, 2002).

Table 1 represents a short version of the dull grading chart because of its wide popularity in literature.

Table1. IADC drill bit dull grading

Cutting structure				Bearing/ Seals	Gauge	Other	Reason pulled
IN	OUT	DULL	LOC				
I	O	D	L	B	G	O	R

The main criteria for examination are eight and they are reviewed one by one after replacing the bit.

A 0÷8 scale is used for the first two characteristics, so when

going to a bigger number, the cutting structure condition (steel teeth, inserts or fixed-cutter) gets worse. The third criterion – dull characteristics (D) – consists of a body damage (if observed): broken or missing teeth, metal tracks, damaged roller cones, etc.

The fourth column marks the roller cones condition (roller cone bits) or the active elements (PDC bits). The fifth column is about the bearing unit condition and its isolation (roller cone bits), or simply a mark for a non-existing bearing unit (in PDC bits). The sixth parameter is important as it is based on the total working hours for any drill bit and is evaluated with specific tools. The seventh column is similar to the third one and marks any other dull characteristics. The final one is the reason for pulling the bit out of hole and replacing it. This may be a planned or an emergency type of operation (Rabia, 2002).

Nature of the conducted research

During the research, five drilling parameters were observed for a period of 5-6 years and for 22 different types of drill bits drilling in different lithological and technical environments: nominal OD [D, m], total drilling meters [ΣM], total working hours [Σh], average WOB [T, t], and average RPM [min^{-1}] (Table 2).

In order to receive as authoritative results as possible, only new bits were included in the research and calculations with current dull characteristics were performed during the pulling out of the hole.

The percentage column (Dull grade, %) in Table 2 is the outcome of an important transformation operation. This transformation is made based on the bit condition and is viewed as uniting all the eight parameters from the bit dull grading chart.

Table 2. Drill bits collected data

Drill bits data		Drilling parameters				Dull grade, [%]
D, [mm]	№	Σ m	Σ drill, hours	WOB, [t]	RPM, [min ⁻¹]	
444.5	5251384	350	89.00	9	40	20
444.5	226375	159	55.50	8	65	15
444.5	5215330	161	114.67	18	50	18
444.5	5231059	155	88.33	16	65	15
444.5	226376	303	133.00	21	75	33
444.5	226832	114	79.92	20	85	20
444.5	5199057	129	121.03	21	100	25
444.5	7022334	326	117.80	7	100	35
444.5	5257123	291	371.25	6	85	32
444.5	218786	39	76.75	6	75	8
311.2	5231642	380	137.80	18	60	35
311.2	5231641	463	147.50	18	55	38
311.2	5231636	52	42.25	18	55	30
311.2	E203421	472	239.75	3	95	20
215.9	227404	20	65.33	9	90	8
215.9	5231977	129	99.75	18	55	20
215.9	N/A	269	136.51	12	75	25
215.9	HP5011	148	188.00	12	85	15
215.9	8685B	8	72.75	4	65	8
215.9	123326	174	37.50	6	85	25
152.4	5248491	238	185.75	8	90	20
149.2	5212575	59	82.18	8	100	6

Last but not least, it is important to emphasise that bit dull grading is affected by one unregulated parameter – the rock formations the bit is drilling in. This suggests for an insignificant error in the statistical model, since the formations cannot be chosen, changed, or regulated.

Dull grading models and analyses

Using the STATGRAPHICS software and in accordance with other researchers' work (Durchev & Minin, 2023), experimental models are brought out showing the connection between dull grading [i, %] and the other drilling parameters (Nedyalkov, 2019).

For research purposes, two regression models are viewed (Tables 3 and 4, respectively).

The first regression model (including a constant) is as follows:

$$i = -0.67 + 0.004 \cdot D + 0.006 \cdot h + 0.05 \cdot M + 0.04 \cdot RPM + 0.65 \cdot T \quad (1)$$

According to Table 3, the multiple correlation coefficient R^2 is 64.0845 %, and the adjusted one R^2 is 52.8609 %, which is relatively low and inappropriate. The **P-criteria** is the so-called **trusted probability** and its critical value is **0.05**. Thus, it is below minimum for all parameters except ΣM and T , but is higher for the constant itself, therefore the model is inadequate.

Table 3. Model parameters including a constant

Parameters	Value	Standard error	T-statistics Student		P criteria
Constant	-0.67	9.37	-0.07		0.94
D, m	0.004	0.013	0.30		0.77
Σh, hours	0.005	0.025	0.22		0.83
ΣM	0.046	0.0129	3.54		0.003
T, t	0.65	0.2603	2.51		0.023
RPM, min ⁻¹	0.039	0.0907	0.44		0.67
	Sum of model squares	Freedom degrees	Average model squares	F criteria	P-importance
Model	1233.8	5	246.8	5.71	0.003
Residue	691.5	16	43.2		
Total	1925.3	21			
Multiple correlation coefficient					64.08 %
Adjusted multiple correlation coefficient					52.86 %
Standard error					6.57
Average absolute error					4.32
Durban-Watson statistics					1.81
Residual auto-correlation					-

Table 4 views the non-constant version of the model.

Table 4. Model parameters excluding a constant

Parameters	Value	Standard error	T-statistics Student		P criteria
D, m	0.004	0.0117	0.31		0.76
Σh, hours	0.0056	0.0239	0.23		0.82
ΣM	0.046	0.0123	3.72		0.002
T, t	0.65	0.228	2.83		0.01
RPM, min ⁻¹	0.034	0.0503	0.68		0.51
	Sum of model squares	Freedom degrees	Average model squares	F criteria	P-importance
Model	11317.3	5	2263.5	55.6	0.000
Residue	691.7	17	40.7		
Total	12 009	22			
Multiple correlation coefficient					94.24 %
Adjusted multiple correlation coefficient					92.89 %
Standard error					6.38
Average absolute error					4.32
Durban-Watson statistics					1.79
Residual auto-correlation					-

The result model is as follows:

$$i = 0.0036 \cdot D + 0.0056 \cdot h + 0.046 \cdot M + 0.034 \cdot RPM + 0.65 \cdot T \quad (2)$$

Similar to the previous case, only ΣM and T are with a trusted probability below 0.05. However, R^2 is higher: 94.2401. Standard and absolute error are close in values. This model can be considered adequate as the adjusted R^2 is a little more than 92%.

Conclusions

The following conclusions are made based on the executed research work:

- Drill bits dull grading is a complexed process, whose numerical value is dependent on several parameters;
- The most important drilling parameters that affect dull grading are total working meters ΣM and average weight-on-bit T ;
- The drilled rock formations have significant influence on

dull grading, but from both statistical and technological points of view, cannot be controlled or replaced.

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