ISSN: 2458-8989

Natural and Engineering Sciences

NESciences, 2018, 3(3): 378-385 DOI: 10.28978/nesciences.469298

- RESEARCH ARTICLE -

Correlating Rate of Penetration with the Weigth on Bit, Rotation per Minute, Flow Rate and Mud Weight of Rotary Drilling

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Abstract
In this study, the effect of some drilling parameters, rotation per minute, weight on bit, flow rate and mud weight on rate of penetration, were investigated in detail. As a result, the rate of penetration was found between 1,79m/h and 14,80m/h, which have a good statistical relationship with the rotation per minute, flow rate and mud weight. On the other hand, it was determined that there was no any relationship between rate of penetration and weight on bit.

Keywords: Rate of penetration, Weigth on bit, Rotation per minute, Flow rate, Mud Weight

Article history:
Received 16 August 2018, Accepted 07 October 2018, Available online 10 October 2018

Introduction

Rate of penetration (ROP) is calculated measuring the length of time required to drill one meter or feet of depth. This is typically done by reading the chart on the geolograph. If we correct calculation of the speed of progress, it gives a lot of economic and time-saving benefits for drilling. It is suggested to calculate and define the effcets of the parameters on the ROP. The factors which affect rate of penetration are exceedingly numerous but these parameters Weigth on bit (WOB), Rotation per minute (RPM), Flow rate (FR) and Mud weight (MW) are the most important for rate of penetration deciding (Annudeep, 2012; Babür&Özüdoğru, 2014; Bharadwajç, 2013; Bourgoyne et al., 1991; Chen&Yue, 2016; Bataee et al., 2014). Analysis of ROP is complicated because of the variables. For example, interpretation of field data may

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involve uncertainties due to the possibility of undetected changes in these parameters properties. In this case, studies of affecting rate of penetrations are always being a meticulous work. While it is generally desirable to increase penetration rate, such gains must not be made at the expense of overcompensating, detrimental effects (Ettehadi, 2007; Hapnes, 2014).

WOB is an essential part of drilling. WOB is measured and reported in tonnes in rotary drilling. Therefore, amount of WOB per application is crucial for drilling operations. If the WOB is higher than the optimum value, the drill bit has a damage. On the contrary, if the WOB is less than optimum range, ROP slows down (Gumati et al., 2013).

RPM is a term that describes how fast a file rotates. It shows the rotational speed of the bottom hole assembly. The measurements for this parameter are accurate as long as the acquisition system set-up has been thoroughly made up (Kallantari et al., 2018; Kök et al., 2018; Kuang et al., 2017; Mahasneh, 2017; Mahmoud et al., 2018; Miyora et al., 2015).

FR is one of the very important parameters to be recorded for optimization purposes. Thus, it is so important for drilling because of lots of tasks. The list the tasks of muds are lubricating and cooling the drill, keeps the well floor clean, moves up the scrap from the well, keeps circulating in the well when the circulation is interrupte, prevents collapse and deterioration of the formation, holds the pipes and balances the weight (Morton&Thompson, 1993; Mutlu et al., 2018; Olsen et al., 2017; Paiaman et al., 2009).

MW is a per unit volume and it is one of the most important mud properties. Because it controls formation pressure and provide wellbore stability. MW is measured and reported in pounds per gallon (ppg), pounds per cubic feet (lb/ft^3), or grams per milliliter (g/ml). MW is normally measured by a conventional mud balance. Mud weight provide pressure to hole back formation. If mud weight is too small, wellbore may collapse (Pedersen&Godhavn, 2017; Tuna, 2010; Xiao et al., 2018).

The parameters of affecting drilling speed can be defined as the provision of real-time data to expedite decision-making based on information. In any engineering study of rotary drilling it is convenient to divide the factors which affect the ROP are WOB, RPM, FR and MW. The parameters recorded for drilling optimization are critically important to be representative of data they are meant to reflect. The parameters under the formation type in Bulkasım-10 Adıyaman are Zırnak formation (Clay Stone), Karakurt formation (Volcanic Rock), sub Zırnak formation (Volcanic rock). Beyond the above stated parameters, determining the ROP is among the most sought after parameters in drilling industry. This is due to the fact that it allows for optimization of drilling parameters to decrease drilling costs and enhance drilling process safety.

In this study, the effect of the drilling parameters (WOB, MW, FR and RPM) on the ROP were evaluated with statistically. Statistical analysis was performed for each parameter and the relationship with the penetration rate was examined.

Material and Methods

Well and Formation

The parameters were taken from the data which were obtained from the well which is located in Adıyaman and named as Bulkasım-I. The well was completed at 3336m with success in 77 days. Formation types and depths are given in Fig 1.

Statistically Analysis

The results of ROP, WOB, RPM, FR and MW of the drilling were analyzed using the method of least squares regression. The equation of the best-fit line, the 95% confidence limits and the correlation coefficient (R^2) were determined for each regression. The ROP values were correlated with the WOB, RPM, FR and MW for each interval.

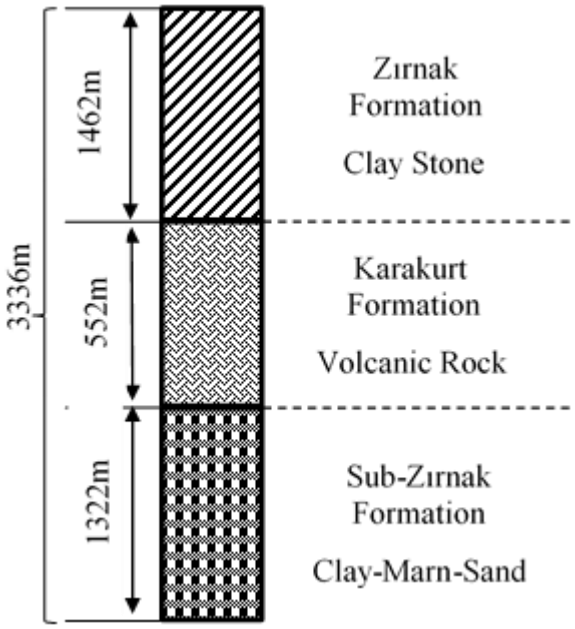

Figure 1. Formation type and depths of Bulkasım-I well

Results

The parameters affecting the drilling speed obtained from the 77 days Bulkasım-I well are given in Table 1. These parameters were processed as statistical data in the form of ROP, WOB, RPM, FR and MW. The graphs are presented in Figure 2-5. And regression analyses results are presented in Table 2. The data and graphs indicated the effect of the parameters on ROP values.

Table 1. Bulkasım-1 well drilling datas

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Interval (m)	ROP (m/h)	WOB. (tonne)	RPM (rpm)	FR (gpm)	MW (lb/ft^3)
0-58	5,27	4	50	487	68
58-574	6	12	110	525	69
574-1033	14,8	12	130	544	69
1033-1060	7,71	12	110	420	67
1060-1596	7,1	10	100	423	69
1596-1910	7,75	10	90	407	71
1910-2130	1,96	10	90	407	71
2130-2208	2,84	12	85	390	72
2208-2444	2,25	14	80	407	72
2444-2710	2,67	14	80	382	75
2710-2736	1,79	7	70	228	75
2736-2818	2,45	12	90	260	75
2818-2970	3,8	11	70	260	75
2970-3163	2,47	11	80	260	75
3163-3336	2,42	10	80	252	75

Table 2. Regression analysis results

Parameters to be related	Regression Equation	R^2
ROP-WOB	$ROP = -0.034(WOB)^2 + 0.684(WOB) + 1.606$	0.02
ROP-RPM	$ROP= 0.003(RPM)^2 – 0.575(RPM) + 24.14$	0.83
ROP-FR	$ROP = 0.000(FR)^2 – 0.070(FR) + 12.27$	0.57
ROP-MW	$ROP = 3E + 21(MW)^{-11.2}$	0.54

The highest speed of our progression is 14.8m/h at where rotation per minutes is 130rpm and also, the lowest speed of our progression is 1.79m/h at where rotation per minute is 70rpm. When the graph is analyzed, the effect of the revolutions per munites on the rate of penetration is calculated as R^2 =83 (Figure 2). In this case, a significant correlation was found between RPM and ROP with a high rate of 83. Although there is a declining line between the speed of progression and ROP for a certain time, it appears that the speed of progress is increased by increasing the ROP.

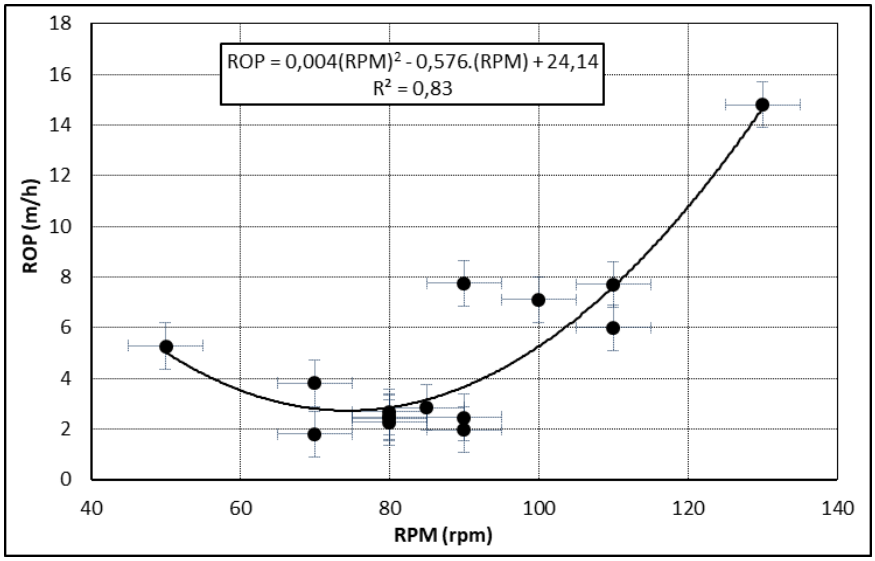

Figure 2. ROP-RPM relationship diagram

Figure 3 showed that FR was found as 544 at the highest speed and 228 at the lowest speed (1.79m/h). Depending on them, the correlation between rate of penetration and flow rate was calculated as R^2 =57 It was seen that the relationship between FR and ROP showed different trend from RPM-ROP.

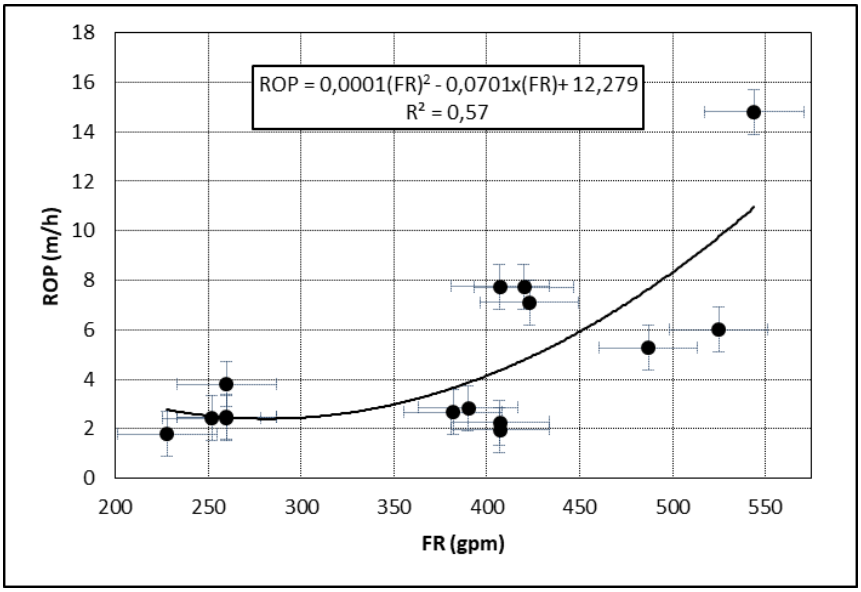

Figure 3. ROP-FR relationship diagram

Examining the graph belonging to the relationship between the MW and the ROP shows that the highest speed of our progression is 14.8m/h at where MW is 69lb/ft3 and also, the lowest speed of our progression is 1.79m/h at where MW is 75lb/ft3. As the MW increases, ROP decreases. In other words, there is an inverse ratio (Figure 4).

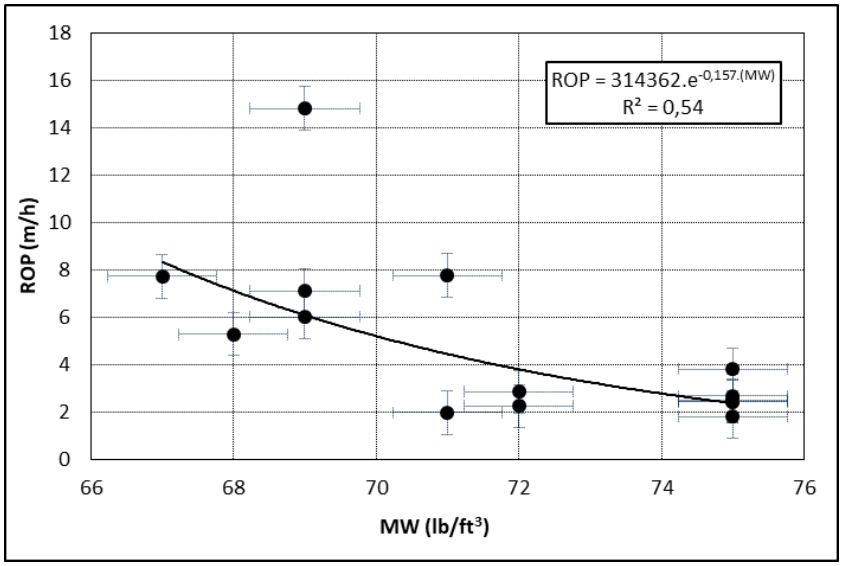

Figure 4. ROP-MW relationship diagram

Unlike other graphs, this relationship between ROP and WOB gives us a different result. When we examine the graphics again the highest speed of our progression is 14.8 m/h at where weight on bit is 12tonne and also, the lowest speed of our progression is 1.79 m/h at where weight on bit is 7tonne. In this case, we can see that there is no regular relationship between these two parameters (ROP-WOB) and also that there is no effect on the ROP (Figure 5).

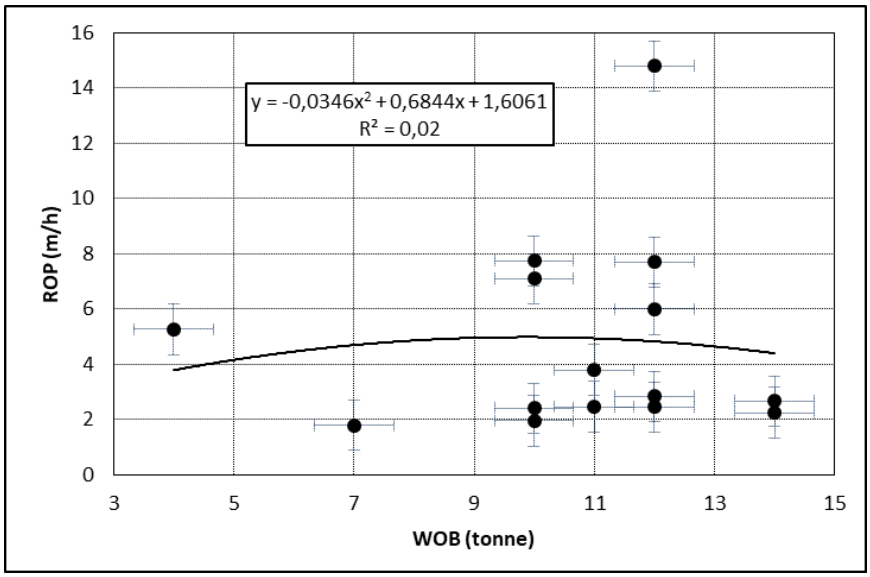

Figure 5. ROP-WOB relationship diagram

Unlike other graphs, this relationship between ROP and WOB gives us a different result. When we examine the graphics again the highest speed of our progression is 14.8m/h at where weight on bit is 12tonne and also, the lowest speed of our progression is 1.79m/h at where weight

on bit is 7tonne. In this case, we can see that there is no regular relationship between these two parameters (ROP-WOB) and also that there is no effect on the ROP.

Discussion

Many parameters which is RPM, MW, FR, WOB affecting the ROP have been examined. Different graphics were obtained for these parameter resulting from the conversion of the data obtained in the Bulkasım-1 Adıyaman region. It was found that there was direct relationship between ROP and RPM, FR, while there was an inverse relationship between ROP and WOB, MW.

When all graphics were interpreted, these interpretations may be made for other drilling information to be made in Bulkasım-1 under these data which are the highest speed of our progression is 14.8m/h at where WOB is 12tonne, MW is 69lb/ft3, the FR is 544 and rotation per minutes is 130rpm. The correlation equations are as follows.

In a conclusion, the equations are practical, simple and accurate enough to apply and are recommended for use in practice.

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