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FULL LENGTH ARTICLE

A study of friction factor model for directional wells

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Abstract High torque and drag is one of the main problems in the directional wells. Friction models can be used for analysis during planning, drilling and after finishing the well. To have an accurate model it is very important to have the correct friction factor. This paper studies one of these models called Aadnoy's friction model. The purpose of this paper is to make an investigation on the limitations of the model, and also to find out how much the model can help for detecting the downhole problems. The author used an Aadnoy's based excel sheet done by TL Longbow Prime company for studying the model. The model has shown reliable results for slant wells which helped to estimate the downhole issue (Bitumen – high viscous oil). Also good torque results had been obtained for horizontal section despite the poor drag results. In the paper three different well profiles has been used during the study.

1. Introduction

Torque and drag result from the friction between the drill string and the wellbore. Torque and drag calculations are very important during planning phase and operating phase of the well. The success of the well can be affected by torque and drag presence especially in deep and complex wells. For instance, high torque and drag forces are important limitations in extended reach drilling because they prevent to reach drilling targets [14]. Therefore, the focus on torque and drag model has been increased by increasing the number of extended reach drilling [7,8].

Running torque and drag model is a very important factor to drill the wells successfully. Usually a model based on frictional analysis is used to study the effect of friction on torque and drag readings. The friction factor is maybe the most uncertain factor in the calculations. This is because the friction fac-

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Abbreviations: 2D, two-dimensional; 3D, three-dimensional; BHA, bottom hole assembly; ECD, equivalent circulation density; ERD, extended reach drilling; ERW, extended reach wells; HD, horizontal departure; HL, the hook load. Displayed by the weight indicator; HKL, the hook load. Signature in real time data file; MD, measured depth; POOH, pulling out of hole; PRS, pick up/rotate/slack off; RIH, running in hole; ROP, rate of penetration; RPM, revolutions per minute; SPP, stand pipe pressure; TVD, true vertical depth; TRQ, torque. Signature in real time data file; WBM, water-based mud; WOB, Weight on bit; RSS, rotary steerable system; PDM, positive displacement mud motor; MW, mud weight; PDC, polycrystalline diamond compact; DD, directional driller; TL, Trant-Logistics Company; PWD, pressure while drilling.

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Nomenclature

α	wellbore inclination, radians	H_r	hook load while rising, calculated in analysis, tons
$\Delta\alpha$	change in inclination over section length, radians	HKL	the hook load, tons [kN]
Φ	wellbore azimuth, radians	L	length of element, m
$\Delta\Phi$	change in azimuth over the section length, radians	MF	mud flow, l/min
θ	absolute change in direction/dogleg, radians	r	radial clearance between wellbore and work string, m
μ	friction factor	R	radius of curvature, m
β	buoyancy factor	RPMB	revolutions per minute or average rotary speed, (–)
F_1	the bottom force of a pipe element, N	s	length of the section, m
F_2	the top force of a pipe element, N	SPP	stand pipe pressure, bar
F_{down}	slacking force, N	T	torque, kNm
F_F	frictional force, N	TJ	tool joint, m [inch]
F_N	side or normal force, N	W	buoyed weight of the pipe, N
F_{up}	pulling force, N	w	unit weight of pipe, kN/m
ΔF	difference in Fup and Fdown, N	W_{tb}	weight of traveling block, tons
H_l	hook load while lowering, calculated in analysis, tons		

tor is not a measured parameter but it is a fudge factor. This fudge factor depends on other effects including mud system lubricity, pipe stiffness, cuttings beds, hydraulic piston effects and tortuosity [18]. To have an accurate model, it is very important to find appropriate friction factors for different drilling situation. To judge any model whether it is good or bad, we have to judge the model quality and how much easy it is to use.

In the present paper, the author will study Aadnoy's friction model by applying real well data for different hole conditions and will compare the model with field data. The main objective of the paper is to study the validity and limitations of Aadnoy's model. Because the fudge factor or the friction factor is one of the important factor for any torque and drag model, the main goal is to model the friction factor for different hole conditions to find out if the model can be used to predict the downhole condition.

2. Literature review

In this section, a short review on the previous work has been done for torque and drag models.

2.1. Torque and drag models review

The first contribution to understand the friction in the well was developed by Johansick [22]. He has developed a torque and drag model based on basic equations for friction in deviated wellbores. In 1987 Sheppard et al. improved Johansick model by changing the model into standard differential equations [21]. In 1993 a well has been drilled in the Wytch Field in England by British Petroleum (BP). The well profile was ERD well with 10.1 km horizontal displacement from the onshore platform. Drilling this well proved to the industry that the targets were earlier seen as out of reach became accessible. From this time extended reach drilling wells increased globally. One of these wells was in Al Shaheen field in Qater with 12.3 km MD drilled by Maersk in 2008 [9]. From these types of wells a more understanding of downhole forces improved the torque and drag models, because they limit distant drilling objects and decide the success of the well [4,12]. In 2001 Aadony and Andersen developed a new analytical solution to present the wellbore frictions [19]. These geometries include straight, drop-off and build up sections. In 2008, Aadnoy et al. [15] made the analytical model simpler and entered the movement of the drill pipes up or down. In 2010 Aadony et al. improved this model for different geometries [12]. The Author had used an excel sheet based on the model done by Aadnoy et al. [15].

Torque and drag analysis has proven to be useful in well planning/design, real time analysis and post analysis. Practically torque & drag model's analyses are a combination of study of historical behavior, improves the experience, utilize engineering models and use of that analysis, to be able to study the well bore condition and reduce the downhole problems. Every time we use the model we have to calibrate the model at the beginning of each section.

2.2. Friction factor

In Coulomb friction model, the friction coefficient between an object and a surface is defined as the ratio of the friction force F between the object and the surface and the normal force N of the object on the surface. The situation is called static, if a force acts on a body, until the maximum friction force is reached. At this moment in time the body starts moving.

The Coulomb friction model can be described in the following Eq. (1) and Fig. 1, can be expressed as.

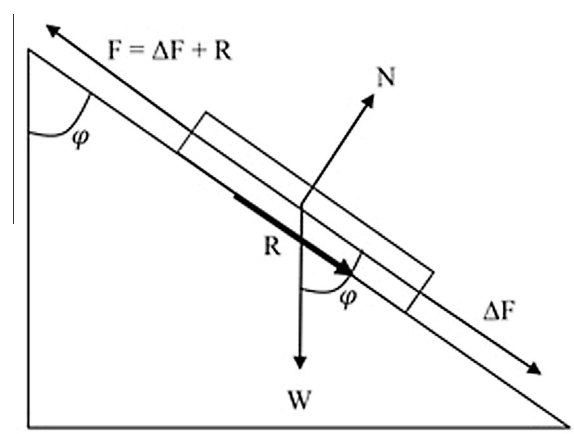

Figure 1 Friction in a deviated well.

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