DETERMINATION OF THE EXTRACTION FORCE OF THE DRILLING GASKET FROM OIL AND GAS WELLS

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Abstract: *Oil and gas wells can be vertical, inclined and horizontal, according to their spatial trajectory. The forces acting when the drill string is extracted are: the force due to the weights of the rod types, friction and inertia forces and the force caused by the action of the drilling fluids. These forces can influence the tensile stress state of the drill string.*
Cuvinte cheie: *force, tensions, drill well, rods*

1. Introduction

The weight and speed of the bit, the maneuver speed (pull out and run in hole) and the hydraulic power transmitted are the operating parameters of the drill string.

The drill string is a mechanically complex system from constructive and functional point of view and the operating parameters are determined by the interaction with the wellbore.

The stresses of the drill string are determined both by the characteristics of the drill string (composition, stiffness, length, diameter) and the wellbore parameters (diameter, rock nature, inclination, deviation, well design), and they are permanently changing due to feed of the bit. The optimal construction and exploitation of the drill string is based on solving a complex of problems such as [4]:

- determining the composition of the drill string on the strength requirements;
- determining the stresses that may occur during work in the wellbore;
- stress analysis in the main sections;
- manufacturing technologies;
- drilling behavior at variable stresses under laboratory and wellbore conditions.

2. The pull-out forces of the drill gasket

Traction load is analyzed in three cases:

a. when the drill string is suspended and the drilling fluid circulation is normal or is stopped
b. during the drilling process
c. in the case of extraction, the drilling gasket

The traction loads that appears when lifting the drilling gasket is influenced by the resistant forces due to friction with the wellbore walls, with the drilling fluid, and also due to wellbore deviation and inertial forces.

In the case of the vertical wells, the following forces act (figure 1): the forces due to the weights of the two types of gaskets (drill pipes G_p and drill collars G_g), the forces due to the action of the drilling fluid (the Archimedes force F_{p1} and the concentrated force F_{p2}) and friction and inertia forces (F_f and F_i).

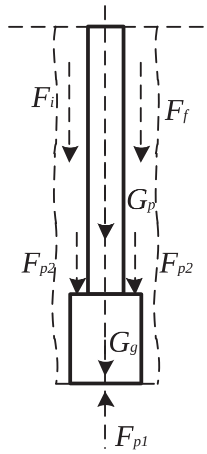

Fig 1. *The forces system to extracting the drilling gasket from the vertical well*

The algebraic sum of the forces occurring when the drill string is extracted it is the total pull out force of the drill gasket:

$$F_e = G_p + G_g - F_{p1} + F_{p2} + F_f + F_i \qquad (1)$$

The weights of the collars are calculated with the formulas:

$$G_p = q_p \, L_p \, g \qquad (2)$$

$$G_g = q_g \, l_g \, g \qquad (3)$$

where: q_p and q_g are the weight of the drill pipes and drill collars;

L_p and l_g – the length of the drill pipes and drill collars;

g – gravitational acceleration.

The forces due to the action of the drilling fluid are:

$$F_{p1} = \rho_n \, g \, L \, A_g \qquad (4)$$

$$F_{p2} = \rho_n \, g \, (L - l_g) \, (A_g - A_p) \qquad (5)$$

where: ρ_n is the drilling mud density;

L – the total lenght of the drill string;

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A_p and A_g – the areas of the cross sections of the drill pipes, respectively the drill collars.

Friction and inertial forces are:

$$F_f = \mu\left(G_p + G_g\right) \quad (6)$$

$$F_i = \frac{a_e}{g}\left(G_p + G_g\right) \quad (7)$$

where: μ is the friction coefficient, $\mu = 0{,}10 \dots 0{,}35$ (the lower values are recomanded for soft rocks and the higher values are recommended for hard rocks);
a_e – pull out acceleration,
$a_e = (0{,}10 \dots 0{,}30)\, m/s^2$
Replacing the relations from (2) to (7), in (1), the pull-out force is

$$F_e = \left(G_p + G_g\right)\left(1 - \frac{\rho_n}{\rho_o} + \mu + \frac{a_e}{g}\right) \quad (8)$$

where ρ_o is the steel density.

For the horizontal wells (Figure 2), three segments are identified: one vertical, AB, one curvilinear, BC, with the inclination angle $\alpha = 90^0$ and one linear (horizontal), CT, reaching the target or the proposed objective.

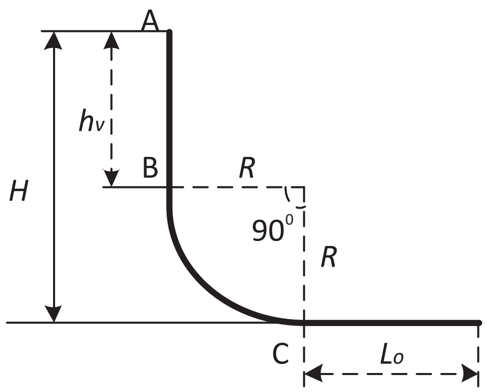

Fig 2. *Profile of the horizontal well*

The working speed on the curvilinear range is reduced, with expensive control costs [1]. The length of these intervals doesn't have to be too big. Usually, the curvilinear range are circular curve [3]. For horizontal wells with the profile from figure 2 the pull-out force is:

$$F_e = F_{AB} + F_B \quad (9)$$

where: F_{AB} is the force for the AB range;
F_B – the force in B point.

$$F_{AB} = f\, q_p\, g\, h_v \quad (10)$$

where: f is the friction coefficient for the vertical range;
h_v – the depth of the initiation of the deviation;

$$F_B = F_C e^{\mu\,\alpha} + q_p g\, R[\sin(\alpha + 2\,\gamma)\, e^{\mu\,\alpha} - \sin 2\,\gamma] \quad (11)$$

where: R is the curve radius of curvilinear range;
α – angle of inclination, $\alpha = 90^0$;
γ – the inside friction angle,

$$\gamma = arctg\;\mu$$

F_C – is the force in C point.

$$F_C = G_{CT}(\cos\alpha + \mu\sin\alpha) \quad (12)$$

where: G_{CT} is the weight for the horizontal range (drain weight);

$$G_{CT} = q_p g\, L_o \quad (13)$$

L_o – drain's length.

It follows that, the pull-out force for horizontal wells can be calculated with the formula:

$$F_e = q_p\, g\,\{f h_v - R\sin 2\gamma + [L_o(\cos\alpha + \mu\sin\alpha) + R\sin(\alpha + 2\gamma)]\, e^{\mu\,\alpha}\} \quad (14)$$

For deviated wells with the three-segment slope profile (figure 3): one vertical, the second curvilinear and the third inclined as a tangent [2]. This profile is the most common.

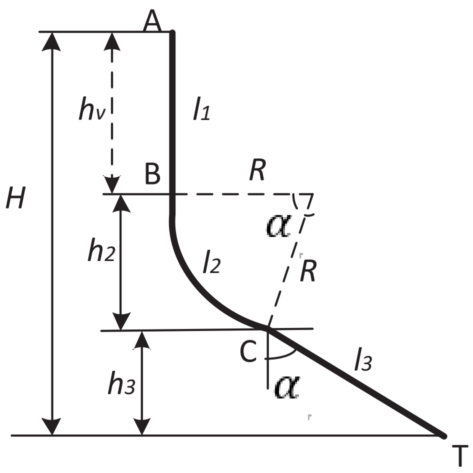

Fig 3. *Profile of the three-segment slope*

The vertical depth of the well is H, and the lenght of the well is:

$$L = l_1 + l_2 + l_3$$

The pull out force of the drill string is calculated with the same relation as for the horizontal wells (relation 14), but the G_{CT} weight is calculated taking into account not only the L_o drain, but also the length of the inclined segment, l_3:

$$G_{CT} = l_3\, q_p\, g \quad (15)$$

3. An example of calculation

For three oil wells, the pull-out forces will be determined. The initial data are centralized in Table 1. The mathematical models presented in the paper are easy to use through a spreadsheet made in Microsoft Excel. The spreadsheets are shown in figures 4, 5 and 6.

Table 1

The vertical well	*The well depth, [m]* *The weight of the drill pipes, [kg/m]* *The weight of the drill collars, [kg/m]* *The length of the drill collars, [m]* *The pull-out acceleration, [m/s2]* *The friction coefficient for the vertical range* *The drilling mud density, [kg/m3]*
The horizontal well	*The vertical depth of the well, [m]* *The drain's length, [m]* *The weight of the drill pipe, [kg/m]* *The friction coefficient, [-]* *The radius of curvature, [m]*
The three-segment slope wells	*The vertical depth of the well, [m]* *Depth of initiation of deviation, [m]* *The weight of the drill pipe, [kg/m]* *The friction coefficient, [-]* *The radius of curvature, [m]* *The angle of tilt , [degrees]*

A. The vertical well

The well depth, [m]	2000.00
The weight of the drill pipes , [kg/m]	28.85
The weight of the drill collars, [kg/m]	174.80
The lenght of the drill collars, [m]	100.00
The pull out acceleration, [m/s2]	0.20
The friction coefficient for the vertical range, [-]	0.10
The drilling mud density, [kg/m3]	1300.00
677144.90	

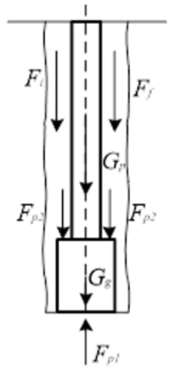

Fig. 4. *The result of the calculation of the pull-out force for vertical well*

B. The horizontal well

The vertical depth of the well , [m]	2000.00
The drain's lenght, [m]	1500.00
The weight of the drill pipe, [kg/m]	28.85
The friction coefficient, [-]	0.40
The radius of curvature, [m]	300.00
283205.55	

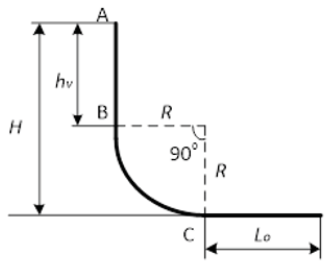

Fig. 5. *The result of the calculation of the pull-out force for horizontal well*

C. The three-segment slope wells

The vertical depth of the well, [m]	2000.00
Depth of initiation of deviation, [m]	1000.00
The weight of the drill pipe, [kg/m]	28.85
The friction coefficient, [-]	0.20
The radius of curvature, [m]	400.00
The angle of tilt , [grade]	30.00
379053.48	

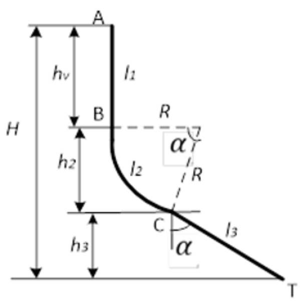

Fig. 6. *The result of the calculation of the pull-out force for three-segment slope well*

4. Conclusions

In vertical wells, pull out forces have high values and create the highest traction loads.

The pull-out forces in horizontal wells increase with increasing curvature rays and increasing friction coefficients.

Considering more values for curvature rays, the pull-out forces of the drill gasket obtained are shown in Table 2 and Figure 7.

In the case of inclined well, the pull-out forces of the drill gasket increase with increasing tilt angle.

Table 2

μ / R, [m]	0,2	0,3	0,4
	The pull-out forces of the drill gasket, [kN]		
100	221,4	306,1	416,3
200	242,0	323,3	430,8
300	262,6	342,0	445,3
400	283,2	359,9	459,8

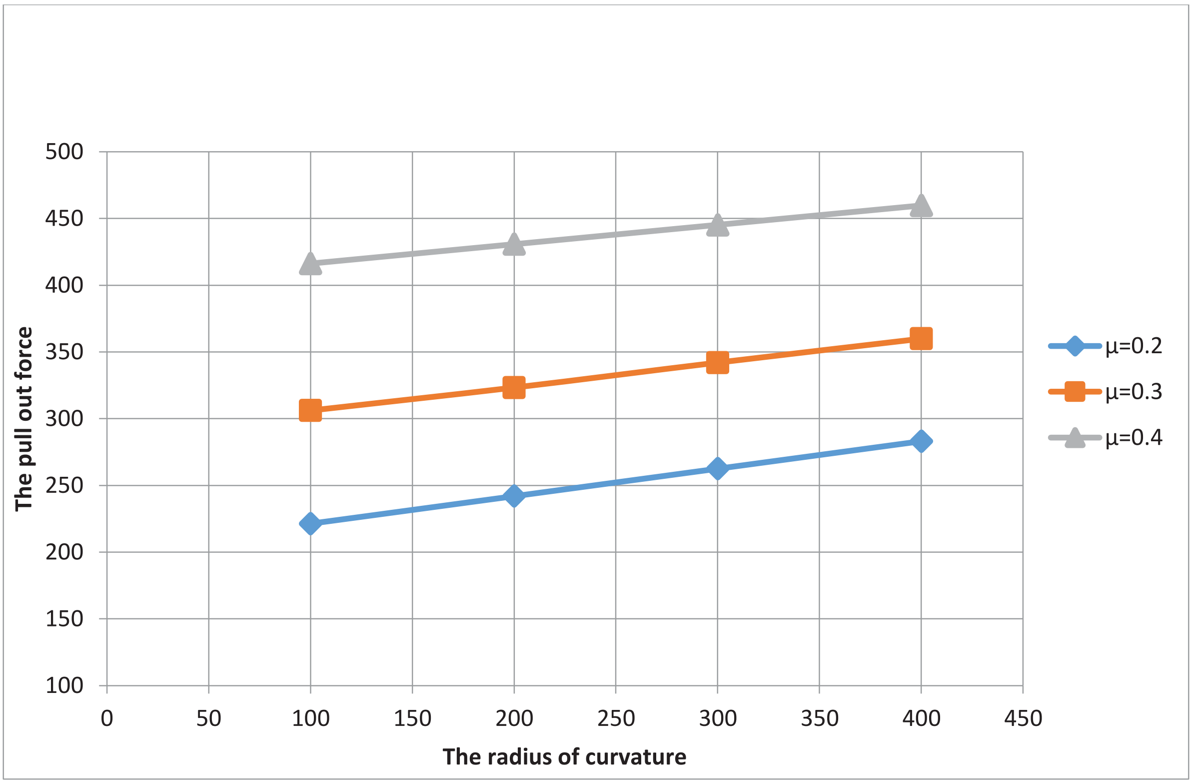

Fig. 7. *The variation of the pull-out forces of the drill gasket according to the radius of curvature and the coefficient of friction*

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