

Research Article

Force and Influencing Factors Analysis for Bottomhole Assembly with Two Stabilizers and One Bend

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Abstract: The aim of this study is to research the force and influencing factors for bottomhole assembly with two stabilizers and one bend. Borehole trajectory control is one of the basic problems in drilling engineering and it is generally paid attention at home and abroad. Experts and scholars at home and abroad have done a lot of research in the drill string mechanics (especially the force and deformation analysis of BHA), interaction of bit and formation, borehole trajectory prediction method. They have obtained many achievements in scientific research, so as to make the hole trajectory control theory and technology constantly develop.

Keywords: BHA, build up, stabilizer, two stabilizers and one bend

INTRODUCTION

At the beginning of 50s, Lubinski using classical differential equation method to analyze BHA mechanical properties of vertical section (Lubinski, 1950). In 1974, Bradley (1974) is cher took the drill string lateral displacement as the basic unknown quantity and solve the bending well eyes assembly stress and deformation with finite difference method. Call as also has analyzed the BHA based on the "balance curvature method" to quantitatively predict the bore hole trajectory. They also put forward bit bending moment theory to express the influence of formation on the deviation. He HuaShan has set up the drill string 3D static large deformation control equation for the first time and use the finite difference method to get its numerical solution. He also founded the vector model for the interaction of bit and formation. Larson considered the BHA mechanical characteristics and bottom rock's function, use half static 3D finite element to write the borehole trajectory prediction software. Mamdouh studied the optimization BHA method and write the FORTRAN optimization software. Lesso used finite element method to analyze the three kinds of BHA characteristics and proposes the use of statistical methods to predict BHA deflecting trend. The objective of this study is to analyze the force and influencing factors for bottom hole assembly with two stabilizers and one bend.

BHA CONTROL EQUATIONS

Many literatures have introduced the BHA statics model and theoretical analysis method (Gao, 1996; Li, 2008). The main method is shown below.

Drill string elastic deformation line arbitrary point radius vector $\vec{r} = \vec{r}(s, t)$, as is arc length, t is time variable. Natural coordinate system is (t, n, b), from the differential geometry knowledge it is known:

$$\begin{aligned} \vec{e}_t &= \vec{r}' \\ \vec{e}_t' &= k_b \vec{e}_n \\ \vec{e}_n' &= k_n \vec{e}_b - k_b \vec{e}_t \\ \vec{e}_b' &= -k_n \vec{e}_n \\ (\)' &= \frac{\partial(\)}{\partial s} \end{aligned} \quad (1)$$

where,

\vec{e}_t = Tangential direction unit vector

\vec{e}_n = Lord normal direction unit vector

\vec{e}_b = The normal direction unit vector

\vec{r} = Point curvature of deformation line is K_b , torsion is $r k_n$, it can be expressed as follows:

$$\begin{aligned} k_b^2 &= \vec{r}'' \cdot \vec{r}'' \\ k_n &= \frac{(\vec{r}', \vec{r}'', \vec{r}''')}{k_b^2} \end{aligned} \quad (2)$$

Figure 1 shows the drill string mechanics calculation element, ignore the shear deformation and

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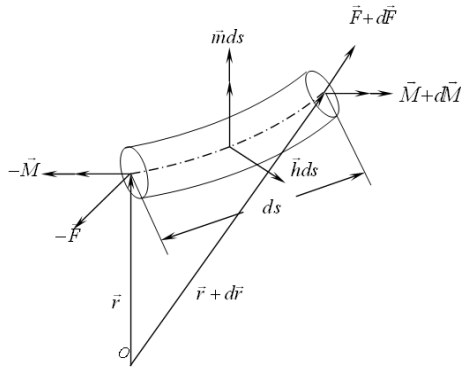


Fig. 1: Infinitesimal element of drill string

vibration damping influence, ignore the dynamic effect of drill string, based on the theorem of momentum and the moment of momentum can get:

$$\vec{F}' + \vec{h} = 0 \quad (3)$$

$$\vec{M}' + \vec{e}_i \times \vec{F} + \vec{m} = 0 \quad (4)$$

where,

\vec{h} = Unit length forces (including surface force and physical)

\vec{F} = Total internal force

\vec{M} = Total moment

\vec{m} = Unit length distribution outside moment, $(\cdot)' = \partial(\cdot) / \partial s$

Take \vec{F} and M as:

$$\vec{F} = T\vec{e}_t + Q_n\vec{e}_n + Q_b\vec{e}_b \quad (5)$$

$$\vec{M} = M_b\vec{e}_b - M_t\vec{e}_t = EI(\vec{e}_t \times \frac{d\vec{e}_t}{ds}) + GJ \frac{d\gamma_T}{ds} \vec{e}_t \quad (6)$$

where,

Q_n, Q_b = Shear force

T = Axial force

M_b = Bending moment

M_t = Torque

γ_T = Torsion Angle

From the ground to the borehole bottom, M_t in a clockwise direction for value.

Taking M_b and M_t into Eq. (3) and (4):

$$\begin{aligned} Q_n' + k_b T - k_n Q_b + h_n &= 0 \\ Q_b' + k_n Q_n + h_b &= 0 \end{aligned} \quad (7)$$

$$\begin{aligned} T' - k_b Q_n + h_t &= 0 \\ -k_b M_t - k_n M_b - Q_b + m_n &= 0 \\ M_b' + Q_n + m_b &= 0 \\ -M_t' + m_t &= 0 \end{aligned} \quad (8)$$

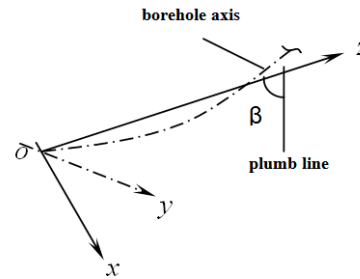


Fig. 2: Reference coordinate system

where,

$$h_i = \vec{h} \cdot \vec{e}_i; m_i = \vec{m} \cdot \vec{e}_i \quad (i = n, b, t)$$

Hypothesis drill string cannot elongation, need to limit conditions $\vec{r}' \cdot \vec{r}' = 1$, derivate the Eq. (6) about s, then take it into Eq. (1):

$$\vec{M}' = \vec{r}' \times [(EI\vec{r}'')' + M_t(\vec{r}' \times \vec{r}'')] - M_t' \vec{r}' \quad (9)$$

Taking the Eq. (5) into (9), after further derivation, we can get:

$$\begin{aligned} M_t' &= \vec{m} \cdot \vec{r}' \\ \vec{F}' &= -(EI\vec{r}'')' + (T - EI \cdot k_b^2)\vec{r}' + (M_t\vec{r}'' - \vec{m}) \times \vec{r}' \\ \vec{h}' &= (EI\vec{r}'')'' - [(T - EI \cdot k_b^2)\vec{r}']' \\ &\quad + [M_t(\vec{r}' \times \vec{r}'') - \vec{r}' \times \vec{m}]' \end{aligned} \quad (10)$$

Take space Descartes reference coordinate system oxyz, as shown in Fig. 1. The z axis passes the o point (bit position) in the borehole axis and A point (stabilizer position); x axis is perpendicular to the z axis and points at the hole of the bottom edge, namely xoz plane for vertical surface, called the drift plane; The y axis is perpendicular to the xoz plane and in accordance with law, the right hand is a yoz plane called the azimuth plane; Origin o is taken in bit place or every across the lower end of the place. β show z axis and the vertical line Angle in Fig. 2.

BHA vertical and horizontal bending deformation control equation are simplified to the following type:

$$u^{(4)} - M_t^* v'' - (T^* u')' = q_x \quad (11)$$

$$v^{(4)} - M_t^* u'' - (T^* v')' = q_y \quad (12)$$

$$(T^*)' = q_z \quad (13)$$

$$M_t^* = M_t / EI \quad (14)$$

$$q_x = q \cdot \sin \beta / EI \quad (15)$$

$$q_y = 0 \quad (16)$$

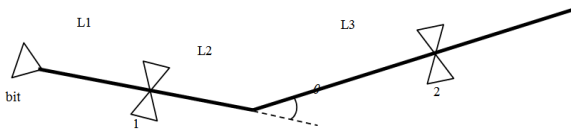


Fig. 3: Structure picture of bottomhole assembly with two stabilizers and one bend

$$q_z = q \cdot \cos \beta / EI \quad (17)$$

$$T^* = (-P + q \cdot s \cdot \cos \beta) / EI \quad (18)$$

where,

- u, v = The drill string elastic deformation online any point along the x, y displacement component, m
- M_t = Drill string torque, N·m
- EI = Bending stiffness of drill string, N·m²
- P = Z force of BHA in the origin of coordinates place, N
- q = Line weight of drill string in the drilling fluid, N/m

FORCE ANALYSIS OF BOTTOMHOLE ASSEMBLY WITH TWO STABILIZERS AND ONE BEND

The structure of bottomhole assembly with two stabilizers and one bend is shown in Fig. 3.

Among them, 1, 2 were nearly bit stabilizer and upper stabilizer, L1 is the distance from bit to nearly bit stabilizer, L2 is distance the diatance from nearly bit stabilizer to structure corner, L3 is the distance from structure corner to the upper stabilizer.

This assembly can realize borehole trajectory build up, drop and hold through the continuous sliding drilling and composite drilling with a combination, already achieved the purpose of continuous drilling, but also need to adjust the hole state, use the tool orientation ability to control, effectively improve the drilling speed and trajectory control accuracy. Single bending two stabilizers assembly choice should not only consider tool deflection ability, but also should consider downhole safety of compound drilling, real time borehole trajectory calculation and prediction should be carried out in construction, timely treat drilling for correction. Below the assembly orientation ability will be discussed in the slide drilling and composite drilling.

Assembly the buildup ability analysis in slide drilling:

The effect of structure corner on bottomhole assembly with two stabilizers and one bend: The assembly structure corner is one of the adjustable parameter, build up capacity depend mainly on the corner. Figure 4 shows that along with the continuously increasing of structure corner and bit side force rapid change large, build rate will change bigger, the law of

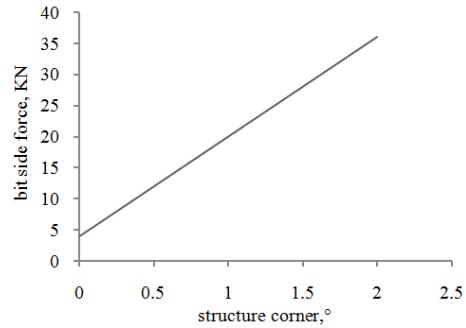


Fig. 4: Effect of structure corner on bottomhole assembly with two stabilizers and one bend

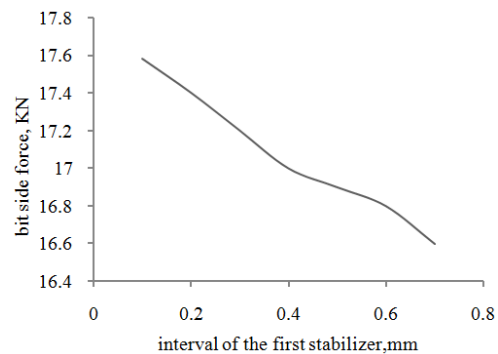


Fig. 5: Effect of first stabilizer interval on bottomhole assembly with two stabilizers and one bend

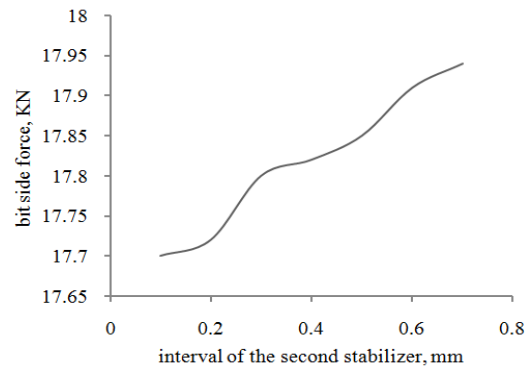


Fig. 6: Effect of second stabilizer interval on bottomhole assembly with two stabilizers and one bend

the variation is linear and improving the curved shell screw drill structure corner is the most effective way to improve the buildup ability. The structure of small corner should be chosen in the long stabilization of composite drilling, because this can reduce friction, reduce hole expanding, prolong the service life of the tool.

The effect of first stabilizer interval on bottomhole assembly with two stabilizers and one bend: Stabilizer interval is equal to the hole radius minus the

stabilizer radius, from Fig. 5, it is known that with the first stabilizer clearance continuously increases, the bit side force decreases, build up rate also decreases, its change law is linear, the first stabilizer welding in the screw drill, can't change at will, in the drilling process should pay attention to its degree of wear, if the wear is serious, the build rate will decrease.

The effect of second stabilizer interval on bottomhole assembly with two stabilizers and one bend: As shown in Fig. 6, with the stabilizer diameter decreases, bit side force increase gradually, they can change the assembly of build up capacity through adjusting the diameter of the stabilizer.

CONCLUSION

- Along with the continuously increasing of structure corner and bit side force rapid change large, build rate will change bigger, the law of the variation is linear and improving the curved shell screw drill

structure corner is the most effective way to improve the buildup ability.

- With the first stabilizer clearance continuously increases, the bit side force decreases, build up rate also decreases, its change law is linear.
- With the stabilizer diameter decreases, bit side force increase gradually.

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