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Study on the Early Warning Method of CBM Drilling Collapse and Sticking

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Abstract: In the process of coal bed gas development, there exist the problems of coal gas collapse and pollution,while now usually useing the changes of ground parameters to judge collapse and sticking,but the accuracy of the method is low, reliability is poor, is not conducive to popularization and application. Aiming at these problems, in this paper, based on the research of collapse and rock drilling jamming mechanism, using the ground monitoring parameters established downhole torque and drag calculation model.Finally using the c# language develop the early warning system for collapse and sticking ,acheeved a precise warning of collapse and sticking in the drilling process.

Keywords: friction, torque, early warning, CBM

1. INTRODUCTION

Coal seam gas as a clean energy and chemical raw materials has been valued by the world's major coal producing countries. There are abundant CBM resources in China, according to the new round of China's land and resources of China's coal-bed methane resource evaluation and prediction, in the depth range of 2000m CBM resources in China is total approximately $34.5\times10^{12}m^3$,and recoverable CBM resources is about$11.0\times10^{12}m^3$[1]. Huge reserves of coalbed methane resources make it as an important vehicle to promote energy production and consumption revolution. However, due to the low mechanical strength and low permeability of coal seam, the gas layer is prone to collapse and pollution, which leads to the decrease of output. Therefore, in order to ensure the safety of CBM drilling and stability of the final production, it must carry out real-time early warning of sticking and collapse. At present, in the preocess of coal-bed methane drilling,usually using the changes of land surface parameters to determine collapse and sticking, judgment accuracy is low, poor reliability. Therefore, this paper puts forward a set of real-time early warning for collapse and sticking that suitable for the process of CBM drilling.And the early warning system is designed and developed, which can be used to analyze the complex situation in the process of drilling well in real time,this has important significance to ensure the safety of coal bed gas drilling and the final stable output.

2. PRINCIPLE ANALYSIS OF COLLAPSE AND STICKING FOR COAL SEAM GAS

Through the study of the mechanism of collapse and sticking find that when the collapse or sticking occurred,it will lead to the downhole torque and friction increases,and downhole torque and friction can be calculated by using the ground survey data. Thus the friction / torque is a reflection of whether the collapse and sticking,and they are the most direct sticking downhole monitoring parameters.So they can be used to establish the calculation model of the friction torque, and judge the downhole situation in real time. When the calculated downhole friction torque is high, that there may be collapsed or stuck underground.

3.FRICTION TORQUE CALCULATION MODEL

3.1 The establishment of calculation model and the early warning process

At present, the trajectory of CBM horizontal wells is usually divided into three sections or five sections,that is “the vertical section and the inclined well section and the horizontal section” or “the vertical section and the inclined well section and the steady inclined section and the inclined well section and the horizontal section”[2-3]. In this paper, the calculation model of the friction torque is established for the three section of the wellbore trajectory. Because of the different curvature of the vertical and horizontal wells, the drilling string and borehole wall contact are different, therefore, the segmented model is used to calculate the friction and torque.Since deformation of drill pipe in the inclined well section, makes it not fully contact with the borehole wall,so need to consider the rigidity of the drill string and the vertical and horizontal bending beam model is used.When the vertical section, the steady inclined section and the horizontal section fully contact with the borehole wall ,since may contain certain curvature change and stiffness larger drill collar and heavy weight drill pipe makes the effect of the rigidity of the cannot be ignored. Therefore, the application of the modified soft model[4]. At the same time because the bottom drill string in drilling process contains special drill large diameter stabilizer and high rigidity of the drill collar, so it should be separately divided into bottom drilling assembly,because the contact between the drilling tool and the shaft wall is mainly the local contact between the elbow and the shaft wall of the stabilizer or the bend joint,and considering the rigidity of the drill string,so still using the vertical and horizontal bending beam model.Modified soft model is built on the soft model,it reduce the calculation error of drill string with large stiffness in the well section for large curvature, improve the calculation precision,also retain the advantage of the original software model,such as the calculation process is simple and fast. The model assumes that the drill string is similar to a soft rod, ignores its rigidity, and ignores the effect of the local shape of the drill string on the friction torque, and ignores the effect of shear force and drill string dynamic effect on the cross section of drill string.When the vertical and horizontal bending beam model is adopted, considering that the length of drill string for kick off section in horizontal well is long, if the original vertical and horizontal bending beam method is used to solve the friction / torque, the large error will be generated.So when solving friction and torque after the establishment of the model,it is through projected the connection point (pivot hinge) to Inclination Plane and Azimuth Plane, and it turn complicate 3-D problem to 2-D problem,then the solution is carried out on the two plane[5]. The early warning process as shown below.

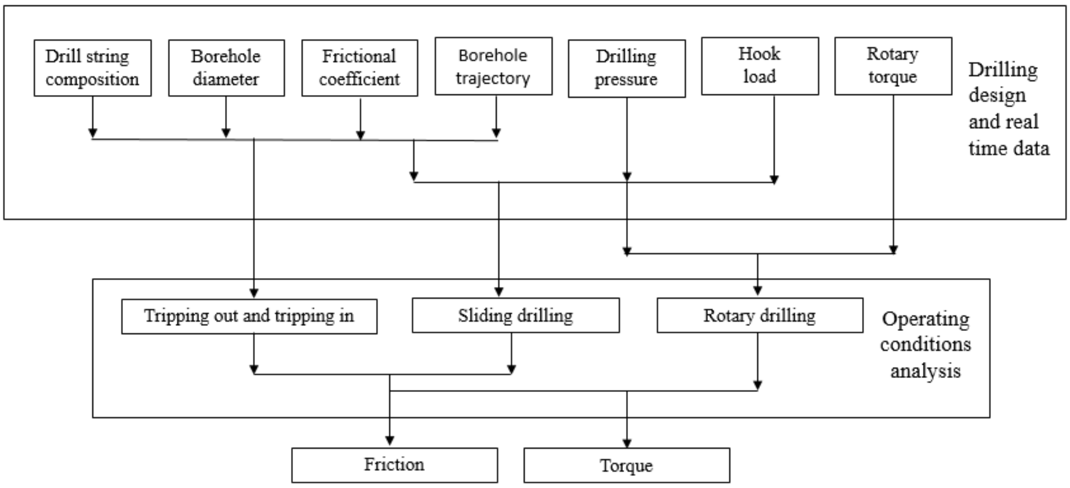

Fig.1 early warning process for collapse and sticking of the CBM

3.2 Model solution

3.2.1 Vertical section friction torque solution

The drill string is divided into a unit segment, and the number is sequentially numbered from top to bottom. The measured parameters of the ground are hook load and drilling torque,then they are respectively took as upper end axial stress and upper end torque of the first unit of a drill string.The axial stress at the lower end and the positive pressure that contact with the shaft lining can be calculated,the formula[8]is as follows:

$$T_{i+1} = T_i - wdl\cos\alpha \pm \mu N_i \tag{3-1}$$

$$N_i = \sqrt{(T_{i+1}\Delta\varphi\sin\alpha)^2 + (T_{i+1}\Delta\alpha + wdl\sin\alpha)^2} + 96\mathrm{EI}[\frac{1-\cos(K*\Delta L)}{K} - (\mathrm{D} - D_O)]\Delta L^{-3} \tag{3-2}$$

$$F_i = \pm \mu N_i \tag{3-3}$$

In the formula: T_i and T_{i+1} are the top end axial stress and the bottom end axial stress of the drill string unit i. N_i is the pressure of the drill string unit i that contact with the shaft lining, F_i is the friction force between the unit i and the shaft lining, w is the buoyant weight of the unit length of drill string, μ is sliding friction coefficient, E is the elastic modulus of drill string material, I is is the moment of inertia of drill string, $\alpha, \Delta\alpha, \Delta\varphi$ are average deviation angle, deviation angle increment and azimuthal angle increment. K is borehole curvature, D is the well diameter, D_O is outside diameter of drill string, ΔL is the length of the pipe string with the additional rigid positive pressure of the drill string and $\Delta \mathrm{L} = [24\,(D - D_O)/K]^{1/2}$. And as the rules that when the drill string movement is upward taken it as positive, while when the drill string movement is downward taken it as negative.According to the critical condition of the foreign scholars who had obtained under the condition of sliding drilling and rotary drilling and the calculation of the lower end of the axial stress,it can be used to determine whether the buckling[6].

Table 3-1 Critical condition for buckling of drill string

load	shape
$\frac{\mathrm{F}}{\sqrt{4\mathrm{EI}\omega \sin\alpha/\Gamma}} \le 1$	No buckling
$1 < \frac{\mathrm{F}}{\sqrt{4\mathrm{EI}\omega \sin\alpha/\Gamma}} \le \sqrt{2}$	Sinusoidal buckling
$\sqrt{2} < \frac{\mathrm{F}}{\sqrt{4EI\omega\, sin\,\alpha/\Gamma}} \le 2\sqrt{2}$	Sinusoidal buckling or Helical buckling
$2\sqrt{2} < \frac{\mathrm{F}}{\sqrt{4\mathrm{EI}\omega \sin\alpha/\Gamma}}$	Helical buckling

When the buckling is not occurs, the N_i invariant,while when the drill string is sinusoidal buckling, the contact force[7]between the drill string and the borehole wall is modified as following formula and T is axial force of drill string, Γ is the 1/2 of difference between the diameter of the hole and the drill string:

$$N_i = \sqrt{(T_{i+1}\Delta\varphi \sin\alpha)^2 + (T_{i+1}\Delta\alpha + wdl \sin\alpha)^2 +} \\ 96\mathrm{EI}\left[\frac{1-\cos(K*\Delta L)}{K} - (\mathrm{D} - D_O)\right]\Delta L^{-3} + \frac{\Gamma T^2}{8EI} \tag{3-4}$$

when the drill string is Helical buckling, the contact force between the drill string and the borehole wall is modified as following formula:

$$N_i = \sqrt{(T_{i+1}\Delta\varphi \sin\alpha)^2 + (T_{i+1}\Delta\alpha + wdl \sin\alpha)^2} + 96\mathrm{EI}\left[\frac{1-\cos(K*\Delta L)}{K} - (\mathrm{D} - D_O)\right]\Delta L^{-3} + \frac{\Gamma' T^2}{4EI} \quad (3\text{-}5)$$

When the buckling occurs, the modified contact force is used to calculate the friction force and the axial force of the lower end by the formula (3-1), (3-2) and (3-4).The obtained axial force is used to determine whether the buckling of drill string occurs and calculate the contact force.With this step, a new contact force is obtained to calculate the new friction force and axial force and then repeat the calculation process.When the difference between the calculation result and the result of the last step is small enough, the cycle can be concluded, and the final result is obtained. The lower end torque of first drill string units is calculated by the formula (3-6), in the formula M_{i+1} and M_i are the upper end torque and lower end torque of the drill string unit I , γ is radius of drill string unit i.

$$M_{i+1} = M_i - \mu N_i \gamma \quad (3\text{-}6)$$

Repeat the above steps, from top to bottom by element calculation can obtain the torque and friction for the drill string of the entire vertical section. In the drilling condition, the drilling string does not occur in buckling, so the calculation without considering the influence of the buckling and the rest of the calculation process and the drill down, sliding drilling conditions are exactly the same.

3.2.2 Inclined section friction torque solution

In the deflection section, the centering device or pipe joint(n) and the upper and lower cut points will divide the drill string into n+1 beams subjected to vertical and horizontal bending loads. The lower end of the axial stress and the lower end torque of last calculated unit in vertical section are arranged as initial condition of steady oblique segment,and three-dimensional analysis of steady oblique segment is decomposed into inclination plane plane (P) and the azimuth plane (Q) plane of two-dimensional analysis,then through the Q, P plane to establish the three-dimensional moment equation to calculate the bending moment of each contact point. According to formula(3-7),(3-8) to calculate the axial force T_{iP} for P plane and T_{iQ} for the Q plane,as well as the counterforce N_{iP}、N_{iQ}, and the counterforce at the contact point is N_i=$(N_{iP} + N_{iQ})^{1/2}$.Formula (3-7) and (3-8) are as follows:

$$T_i = T_{i+1} + \frac{1}{2} q_{i+1} L_{i+1} \cos\alpha_i + \mu\sqrt{(T_{i+1}\Delta\varphi \sin\alpha)^2 + (T_{i+1}\Delta\alpha + q_i L_i \sin\alpha)^2} \quad (3\text{-}7)$$

$$N_i = \frac{m_{i+1} - m_i + T_{i+1}(y_i - y_{i+1})}{L_i} + \frac{m_{i-1} - m_i + T_i(y_{i-1} - y_i)}{L_{i-1}} + \frac{q_i L_i + q_{i-1} L_{i-1}}{2} \quad (3\text{-}8)$$

Upon completion of the above calculation, the friction and torque at the first i cross section at this time are calculated as formula(3-9)and(3-10).

$$M_i = \mu N_i \gamma \quad (3\text{-}9)$$

$$F_i = \mu N_i \quad (3\text{-}10)$$

In the formula(3-7)to(3-10), q_i is the unit mass of the No.i cross drill string in the drilling fluid, M_i is the bending moment at the first i fulcrum, L_i is the length of the first I cross grip and y_i is the first i coordinates of the support.Repeat the above steps, from top to bottom by cross calculations,then the friction and torque of the entire drill string of the oblique section can be obtained.

3.2.3 Horizontal section friction torque solution

The calculation method of the friction and torque of the horizontal section is the same as the straight shaft section.The friction and torque of the i+1-th in the oblique section are took as the initial conditions of the horizontal section to solve the friction and torque of the drill string in the vertical section.

3.2.4 Bottom hole assembly friction torque solution

In the process of CBM well drilling, the axial stress and torque of the bottom part of the unit are used as the initial conditions of the bottom assembly section.The friction and torque are calculated through the longitudinal and transverse bending beam model as well as the oblique section.And the underground friction and torque can be calculated by the formula(3-11) and (3-12).

$$F = \sum_{I=1}^{n+1} F_i \quad (3-11)$$

$$M = \sum_{i=1}^{n+1} M_i \quad (3-12)$$

The measured parameters of the ground parameters of hook load and drilling torque are calculated as the initial conditions. Then calculate the BHA section and take the results to carry out real-time early warning of sticking and collapse.

4. FIELD APPLICATION

According to the above calculation model is established in this paper, the friction and torque are calculated and the CBM drilling drill collapse and sticking analysis software for real-time warning is developed.The calculation and analysis of a horizontal well in North China oil field are carried out by using the software.

The well is a U type horizontal well,and vertical depth of the target is 707.15 meters, the horizontal displacement is 1100.65 meters, and deflection point of the target is 452.85 meters.In the process of the third section,the bottom hole assembly is that,a bit with a diameter of 152.4mm,a single-screw bending with a diameter of 120.7mm(1.5 °),a drilling tool check valve,a circulating sub(MWD with gamma),two Non-magnetic heavy weight drill pipes with a diameter of 88.9mm, 99 drill pipes with a diameter of 88.9mm, 39 heavy weight drill pipes with a diameter of 88.9mm,a while-drilling bumper sub with a diameter of 120mm and a heavy weight drill pipes with a diameter of 88.9mm.In this well 0~580m is the surface casing section, 580~732m is the technical casing section and the rest is bare well section.The simulation condition is that, the casing internal friction factor is 0.25, the open hole friction coefficient is 0.30.

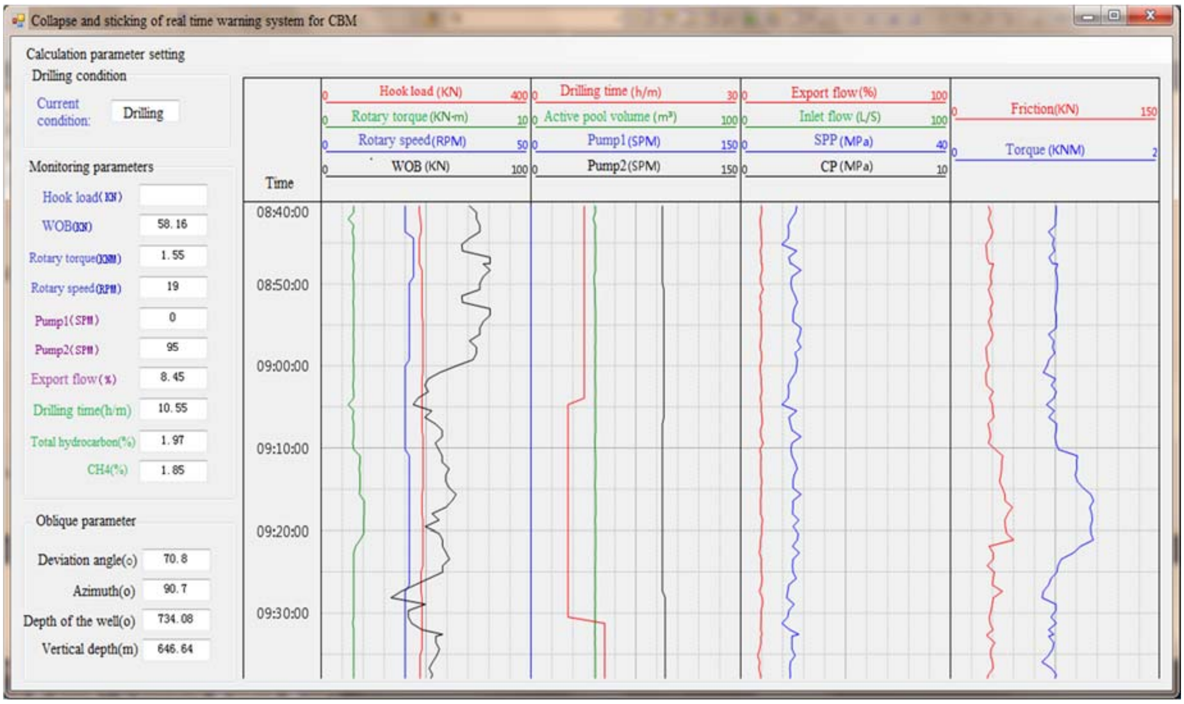

Fig.2 real time calculation curve of downhole frictional and torque

The real-time calculation curve of the downhole frictional and torque are shown in Figure 2.Through the analysis, it is known that the friction and torque are changed greatly at the 9:10:00,indicating a high risk of collapse occurs at this time. The actual situation of the construction site shows that the collapse occurred,and it is indeed to verify the accuracy of the calculation model,also verify that the friction and torque in real time to achieve extreme downhole drilling process collapsed and sticking real-time warning is feasible.

5. CONCLUSION

In this paper, through the analysis of the mechanism of collapse and sticking, put forward a method for real-time early warning of collapse and sticking that suitable for the process of CBM drilling,and completed the establishment of the calculation mode and the development of the software with c# programming language. Field application results show that the real-time warning results for collapse and sticking are consistent with the actual situation of construction site,and it has a a good application prospect.

REFERENCES

[1] Changbo Che,Hulin Yang,Fubing Li,Chenglin Liu et al(2008).Prospect of exploration and development of coalbed methane resources in China.*China mining magazine*.17(05),1-4.

[2] Guangdi Fan,Lugeng Huang et al(2013). Calculation model of frictional torque of horizontal well pipe string, Oil Drilling & Production Technology, 05:22-25.

[3] Thor Viggo Aarrestad(1994). Torque and Drag-Two Factors in Extended-Reach Drilling. SPE 27491.

[4] Vadim Tikhonov ,Khaydar Valiullin(2013). Dynamic Model for Stiff String Torque and Drag. SPE163566.

[5] Juan Li, Shizhong Tang et al(2009). Chenghai District, a large displacement horizontal well friction torque research and Application, Drilling & Production Technology, 03:21-25

[6] Feng Liu(2005). Nonlinear stability analysis of drill string in directional well. Nanjing:Nanjing University of Aeronautics and Astronautics

[7] Xiangzhen Yan, Maosheng Li, XiuJuan Yang,Deli Gao(2007). Study of contact force between drill string and borehole wall in constant-curvaturewellbores, 01:91-94,113

[8] Deli Gao,Chengjing Qin,Wenyong Li(2003). Research on numerical analysis of drag and torque for Xijiang Extended ReachWells in South-China sea. Drilling & Production Technology, 05:7-12.