Influence mechanism of the rubbing of drilling pipe for the stability of hole wall

HAN Xiao-ming, LUO Chen-xu, WANG Shi-feng

School of Mechanical and Power Engineering, Henan Polytechnic University, Jiaozuo 454000, China

Abstract*—The hole wall appears because of the gas drainage of the coal seam, the hole wall is divided for the elastic area and plastic area, according to the elastic mechanics and rock mechanics established borehole wall stress model, caused by gas drilling secondary stress makes the hole wall instability are analyzed, also on the borehole wall by drill pipe contact friction caused by hole wall instability mechanism was studied and obtained the main reason which causing the borehole wall instability is the impact of drill pipe.*

Keywords—drill pipe, gas extraction, hole wall instability.

I. INTRODUCTION

Our country have a lot of high gas occurrence, the proportion is very high, ground stress and gas pressure around the borehole. During the drill pipe drilling, drill pipe appear strong vibration and drill pipe and hole wall have a great impact, it is prone to sticking, burying drilling, hole collapse, collapse and other inner hole accident. Chen.S.L have a study to the effect of longitudinal vibration of drill string, stick slip vibration and vortex movement of drilling to the bit weight, Analysis vortex will have little impact on the drill pressure and torque, but vortex phenomenon is a very severe vibration, that is a big damage for drill pipe and drill bit[1].Yanqiang Liu[2] using dynamics method, and have a stress analysis to drill string and Established the mathematical model of drill pipe column and wall friction contact, simultaneous the mathematical model of Wilson - theta method and Newton RaPhson method can solves the drill pipe string mechanics problems effectively. Liu Qingyou[3-4] trial and others regard the elastic mechanics and numerical analysis as a guide, in the simplified boundary conditions to establish the drill string torsional vibration finite element dynamic model under the simplified boundary conditions. Accords to the wave theory, Gow etc[5] established the mathematical model of the longitudinal vibration of the drill pipe, and analyzed with the drill pipe length change of the natural frequency changes. Zhang Yanglie and other research on the kinematics and dynamics of the drill string and so on. They do a lot of work, and make a great contribution. Yong, Li Zifeng et al. Summary of the many practical engineering case, they research the cause of the failure destruction of drill pipe under various stresses, and establishes a set of numerical model of drill various vibration form. For the future further research laid the theoretical basis[6-7] . Accords to Lagrangian equations Li Qiongqiu established drill string system three-dimensional finite element mechanical model, and unit of kinetic energy, potential energy and damping matrix, mass matrix, stiffness matrix and load matrix are obtained by using the energy method, the differential equation is applied to the numerical calculation method of drill string vibration of computer simulation[8]. From the published academic papers of home and abroad of the, the above content for petroleum and geological exploration drill string vibration, the study status, the loose outburst coal seam gas drainage drilling rod vibration analysis of literature is still relatively small.

Because coal seam hole wall was influenced by combined effect of geological conditions, gas pressure, surrounding rock stress force, the vibration generated by the drill pipe has a great influence on the overall drilling or drilling, the impact of drill pipe and the coal hole wall is caused by one of the main reasons for the hole wall instability. This will be the impact force induced by coal seam and coal hole wall drill hole wall instability collapse phenomenon analysis.

II. MECHANICAL ANALYSIS OF IMPACT BETWEEN DRILL PIPE AND HOLE WALL

2.1 borehole wall stability analysis

Coal seam hole wall stability is affecting the use of gas efficient pumping is a decisive question and the stability of hole wall rely on rock strength and initial stress state. According to elastic mechanics, the vertical stress and horizontal stress in the elastic region is the distance from the free surface and the supporting force peak. The plastic and elastic zone of abutment pressure distribution formula was $\sigma_t = K\gamma H e^{\frac{2f}{M\beta}(x_0 - x)}$, $\sigma_p = \tau_0 \cot\varphi \frac{1+\sin\varphi}{1-\sin\varphi} e^{\frac{2fx}{M}\left(\frac{1-\sin\varphi}{1+\sin\varphi}\right)}$.

This shows that during the process of drill pipe drilling, the ground stress encountered different.

In the gas drainage operation process, drilling hole wall in coal gas force under deformation and secondary stress. Based on the theory of rock mechanics, the coal bed

micro unit $dv = r^2 d\theta^2 dr$. The porosity of the fracture zone (brittle deformation zone) and the elastic deformation zone are respectivelyA1, A2, and the gas pressure is P P0. Stress band as shown in Figure 1.

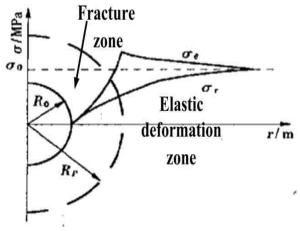

Fig.1:Secondary stress distribution around hole wall

From Figure 1 shows that, during bits of broken coal seam drilling process, a bit not only in the axial direction of the guide drilling, also due to a bit role, which makes the drill drill into the coal wall crack, which produce brittle failure, coal wall under local pipe impact crushing the deformation of the coal will be further increased, the instability of buried hidden dangers for the hole wall. In the surrounding areas of the elastic deformation region, this region mainly maintains the coal seam the stress dynamic balance.

From the (1), (2) we know, It has nothing with crustal stress, and the effects on the stability of coal body conditions are: the coal body friction angle, cohesive force, porous coal and coal body gas pressure. In fact, in cataclastic deformation of coal wall hole is no collapse, collapse of hole, because in the coal micro unit coal concentrated support line force in a state of relative balance of unstable. Gas drainage drilling, coal micro unit three to force to change into two to stress pattern, coal wall shear, compressive and tensile ability began to decline, at this time, coal wall produced secondary stress makes the coal around the hole wall of coal by dual acting, coal hole wall stress more complex, increase the possibility of local coal hole wall instability, under the external force (drill pipe vibration and collision induced, collapse, collapse hole, jet orifice, hold the accidents in the drilling hole.

2.2 Stress of hole wall stability analysis

When drilling in the coal seam, it is assumed that the drill pipe is a rigid drill pipe, and the coal wall is a flexible wall. The following figure 2 is the drill pipe and coal seam hole wall finite element mesh model. Drill pipe and hole wall collision and contact drill pipe length (i.e., the distribution of the depth of borehole and coal seam hole wall about is very complex nonlinear problem, in the drilling process of drill pipe, drill pipe and the coal seam hole wall collision is randomly distributed, which is mainly determined by the borehole bending degree, borehole irregularity makes the drill pipe bending stress situation becomes more complex. Drill pipe and coal hole collision makes deep hole in the wall of the internal wall of hole collapse situation become unpredictable, collapsing internal coal seam to produce "the drill hole" [11], the operator do not know the inside condition and continue to operating , drilling holes caused by "the drill hole" coal occlusion of annular space, makes the high pressure gas and gas cannot successful education, pressure surge in local space, when the stress of the coal body balance is broken, nozzle phenomenon occurs. Because the impact of drill pipe in the hole, the coal hole elastic reduced coal fracture and primary porosity gas accelerated the resolution of gas and coal body under the gas seepage have secondary stress, further exacerbating the hole wall instability.

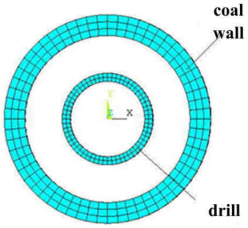

Fig. 2: FEM mesh of drill and coal wall

2.3 Collision condition between drill pipe and coal hole wall

As a result of the contact impact of drill pipe and the coal hole wall of gas pumping drilling stability is very important, also the influence of dynamic properties of this kind of phenomenon of the drill pipe is great, so it is necessary for us to the drill pipe and the coal hole wall collision force to carry on the research and analysis. Figure 3 shows the movement of drill pipe and hole wall.

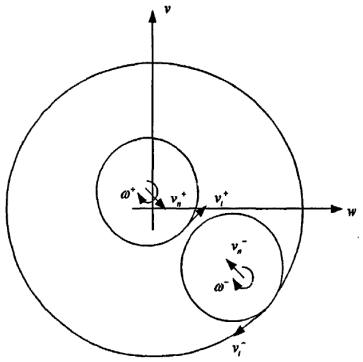

Fig. 3:Sstate of motion of the hole wall

In order to simplify the calculation difficulty, we extract the node on the drill pipe and the wall of the hole coal as the research object, as shown in Figure 3, contact point tangential vector *T*, vector method n , contact point of relative sliding velocity v_f , velocity at the center O of the circle of decomposition: cutting speed v_T and method to velocity v_n , angular velocity ω, From kinematics:

$$v_T + v_n = \frac{D_0}{2}\omega$$

Analysis of the collision between the drill pipe and the coal hole wall, The two time point of the collision moment is t^+ and t^- , the speed is v_T^+, v_n^+, ω^+ and v_T^-, v_n^-, ω^- , the collision between the drill pipe and the coal wall. Sketch of collision between drill pipe and coal wall, As shown in figure4 .

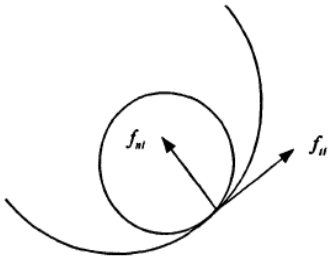

Fig.4: loads on node

Set collision time Δt ,momentum theorem:

ormal friction for cNe: $f_{ni} = \Delta m(e-1)\sqrt{\dot{v}_i^2 + \dot{w}_i^2} / \Delta t$

In the collision process of the drill pipe and the coal seam, on the one hand in the collision of drill pipe, coal around the hole wall of coal body generates cataclasites, but did not collapse, but in under the action of shear friction of drill pipe will cluster coal body blow, fall down, coal body will absorb the kinetic energy of the drill pipe, wave energy (stress wave transmission in coal, superposition, when encountered soft coal seam, the collision will cause the local coal collapse and even lead to the drilling failure; on the other hand, drill pipe and the coal wall collision friction makes the drill pipe wall thinning, the torque capacity to bear down, and then accelerate the drill rod fatigue damage. In addition, the pipe friction will make the drill pipe temperature, it is very dangerous for gas drainage drilling.

III. TEST ANALYSIS OF INTERACTION BETWEEN DRILL PIPE AND HOLE WALL

Figure 5 shows the drill pipe in rotation drilling imaginary running state, time t = 0, drill pipe running state as the horizontal axis drilling. This is an ideal drilling process, the reality is impossible to achieve. Time t=1, bending pipe subjected to drilling pressure under the drill pipe, the normal working condition is still exist at this time.

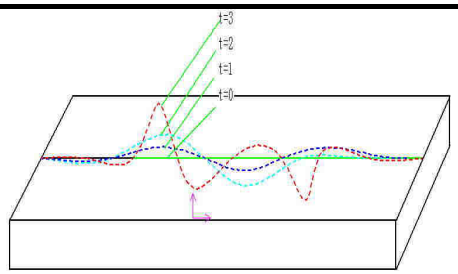

Fig. 5: Motion state of drill pipe in coal wall

At time t = 2, drill pipe in the drilling pressure, centrifugal force, drill pipe coupling vibration, bending stress the role of start collision contact with the coal hole wall. At time t = 3, the drill pipe and the coal hole wall occurred severe impact, this time often is the stage of drilling pipe breaking drill, fatigue failure and hole wall collapse, hole collapse, drill holding etc. phenomenon, more serious is in high gas should force, secondary severe large area spraying hole accident occurs in the combined action of the impact force and drill pipe vibration.

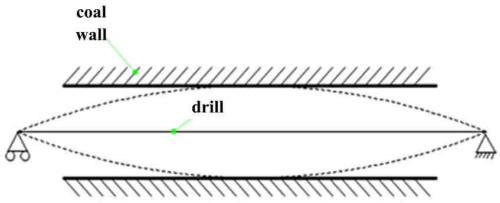

Fig.6: Collision analysis model of drill pipe and coal hole

Such as drill pipe and hole wall collision model diagram is shown in Figure 6, in a deep hole in the drill pipe bending drilling which form a plurality of pivot in the hole, drill pipe and the fulcrum of the composition such as the collision model shown in Figure 6, the drill pipe and the coal hole wall collision process is more violent. Let us analyze the multi point collision analysis on the stability of hole wall, respectively selected coal hole diameter 110mm and 133mm coal hole of the force curve are shown in Figure 7 and figure 8.Such as drill pipe and hole wall collision model diagram is shown in Figure 6, in a deep hole in the drill pipe bending drilling which form a plurality of pivot in the hole, drill pipe and the fulcrum of the composition such as the collision model shown in Figure 6, the drill pipe and the coal hole wall collision process more violent. Let us analyze the multi point collision on the stability of hole wall, respectively selected coal hole diameter 110mm and 133mm coal hole and the force curve are shown in Figure 7 and figure 8.First, we analyze the coal hole diameter to the hole wall stability of 110mm cases, the stress diagram as shown in figure 7.

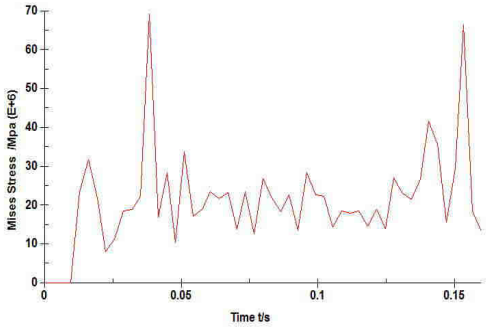

Fig. 7: Stress curve of coal wall

At the coal hole diameter is 133mm, initial conditions applied to drill hole wall and radial velocity of coal 5.68m/s collision, the stress reached 196Mpa, increased due to superposition of bending stress and pipe vibration frequency resonance, resulting in coal drill pipe and hole wall violent collision, similar to the "pendulum" movement in the drill pipe in the multi pivot will have a great impact on the experience of coal and coal wall, the impact of coal hole made by the drill bit to break the formation process of fractured zone and the plastic zone expands gradually, gradually to the crack of coal body elastic region expansion, the coal hole in the pipe under the impact of broken down. While the coal hole wall and increase parsing speed in coal gas accelerated the hole of high gas stress further increased, the collapse of coal slag is not smooth or blocking the coal hole. When the collapse of coal is blocked to a certain extent, in the drill pipe and the coal hole wall gap gas and by the pumping station supplying high-pressure gases under the combined action of that poor slagging coal hole will occur orifice accident, emitted a large number of coal will bury workers, or in advance of the coal mining process, the destruction of the original coal wall, inside the coal body there have been stress crack, drilling in the process of impact vibration accelerated the crack propagation, phenomenon of the drainage drilling process easily in one occurrence of coal body collapse, drill rod locking will occurred.

Due to increase of the drill pipe and the coal wall contact friction, on the one hand, will accelerate the drill pipe abrasion of the drill pipe early retirement; on the other hand, due to the expansion of the fragmentation of the coal wall, the coal stress re distribution in local gas zone may be a high stress, the coal body resistance to deformation can be reduced. At this time, coal and surrounding rock stress in steady state and under the drill pipe touch friction disturbance force under, the coal wall will occur instability phenomenon.

From knowledge of different coal and rock mechanics parameter test and the young's modulus of coal and rock range is 1135~4602MPa, Poisson's ratio 0.18~0.42 and the compressive strength of coal and rock 19.5~119MPa, the vast most distribution in 40~60MPa. From this analysis shows that reducing collisions by the coal hole wall drill pipe stress values can be plastic deformation zone of coal seam break, in collision friction of drill pipe under the action of the hole Bimei resistance to shear deformation ability. This is an important reason of drilling hole gas drainage rate is low, at the same time is also the main reason for fatigue damage of drill pipe.

IV. CONCLUSION

According to the theory of elastic mechanics and rock mechanics established borehole wall stress model, analysis the stability of hole wall stress factors, the drill pipe touch seam hole wall stability under the influence of friction are analyzed. At the same time, according to the mechanical parameters of coal and rock which is known，that drill pipe of the collision and friction stress is the main reason for the future to improve the coal seam gas drainage drilling depth and efficient operations .

ACKNOWLEDGEMENT

The authors are grateful for the funding of this work by the Henan province education department applied research project fund (15A440004, 16A460005) and Henan Province Safe Production Technology Development Plan (H12-094).

REFERENCES

[1] Chen,S.L., Blackwood,K., Lamine E..Field Investigation of the Effectsof Stick-Slip,Lateral,and Whirl Vibrations on Roller Cone Bit Performance. SPE 56439, 1999：1-10.

[2] Liu Yanqiang. Study on drillstring in annulus 3D double nonlinear dynamics. Journal of mechanics, 1998, 30 (1).

[3] Liu Qingyou, Ma Dekun, Tang Xiaowen. Drill string longitudinal vibration model of establishing and solving methods. Southwest Petroleum Institute study report 1998, 20 (4).

[4] Liu Qingyou, Huang Bensheng. The establishment and solution of lateral vibration model of roller bit. Natural gas industry, 2001, (4).

[5] Sun Yuning. Zhao Zhuang drilling technology research should be easily collapse hole coal seam drilling technology research study report [R]. Henan: Henan University of science and technology, 2010,13-16.

[6] Li Zifeng, Zhang Yonggui. Analysis of longitudinal and torsional vibration of drill string. Engineering mechanics.2006 (4):203-209.

[7] Zhou Yong. Analysis and Research on longitudinal vibration model of existing drill string. Journal of oil and gas.2006 (4):146-150.

[8] Qiu Liqiong. Establishment and solution of dynamic mathematical model of drill string. Journal of Chongqing University. 2002(5):148-151