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Nonlinear Dynamics Research between Drill Pipe and Coal Hole Wall during Gas Extraction Drilling

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Abstract

This paper analyzes the impact of gas drainage borehole drilling rod vibration phenomena stability.Taking 100m hole depth in underground coal mine as an example, the dynamic simulation analysis of the underground gas drainage drilling rod was carried out by using the ANSYS finite element dynamic analysis module LS-DYNA method.According to the collision course between the drill pipe and the coal hole wall, the Lagrange algorithm is introduced to analyze the stress change of drill pipe in the collision course of 98mm, 108mm, 118mm and 128mm. The failure mechanism of drill pipe fatigue fracture and hole wall instability caused by the collision between drill pipe and coal hole is analyzed. The results show that the stress caused by the impact of drilling speed, drilling pressure and coal hole diameter is larger than that caused by the collision between drill pipe and coal wall.

Keywords: *drill pipe; gas drainage; torsional vibration; hole wall instability*

1. Introduction

The nonlinear dynamic analysis of the drill string began in the 1960s, main on research and analysis of the axial and torsional vibration of the drill string, the research method is the differential method. Finnie and Bailey through the experiment and the method of trial and error in the case of neglecting damping calculated natural frequency of drill string in 1960.Millheim K and AposstalM using D'Alembert's principle, in the case of inertia force and friction to consider the static analysis, and the establishment of a three-dimensional finite element model of BHA dynamics in the 1980s [1-3]. 1984 to 1985 Dunaycvsky V et al study the condition and stability of precession in directional wells of the drill string, and determine the relationship between drill string vibration parameters of resonance area and drill pipe drilling speed, provides a theoretical basis for [4-5] for the study of drill string lateral vibration. Gao Yan [7] et al according to the wave theory, the mathematical model of drill pipe longitudinal vibration is established, and the change of the natural frequency with the length of the drill pipe is studied and analyzed. Zhang Yanglie et al to study the kinematics and dynamics of drill string and so on to do a lot of work, and make a great contribution. Zhou Yong, Li Zifeng [8-9] and others summed up a lot of practical engineering case, study the drill pipe in a variety of stress situations, and the cause of the failure of the drill pipe all kinds of vibration mode to establish a set of numerical model, for the further research work in the future establish the theoretical foundation [10-11]. Qiu Liqiong according to the Lagrangian equation, the three-dimensional finite element model of drill string system was established, and the kinetic energy, potential energy, damping matrix, mass matrix, stiffness matrix and load matrix of the element were calculated by using the energy method. The numerical calculation method of was used to simulate the vibration of drill string [12]. From the domestic and foreign published academic papers, the literature on the vibration analysis of the soft outburst coal seam gas is still relatively small, the above content is the research status of drill pipe string vibration in petroleum and geological exploration, but the gas drainage pipe and the exploration drill pipe in some aspects of the stress situation has the similar, the research of gas drill pipe is also has the very big reference function. This paper intends to use the way of theory analysis and numerical simulation, combined with the rock breaking theory and nonlinear dynamics theory, the drilling operations in soft coal seams when the nonlinear dynamic characteristics of drill pipe, hole wall is impacted by the tool collision simulation model is established, the caused by collision of coal and rock stress change rule of hole wall is studied,

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to reveal the drill hole wall instability caused by collision, drill pipe fatigue damage and fracture mechanism.

2. Running State Description of Drill Pipe

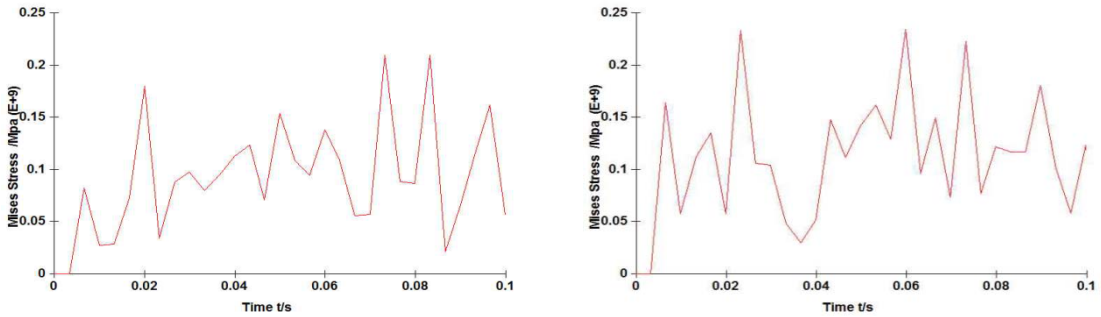
Analysis of drill pipe and the coal hole wall contact key is the problem of nonlinear dynamics research of drill pipe, the collision process of the drill pipe and the coal hole wall and other contact impact problems are quite different, because the drill rod is a root connected through the screw thread hollow slender rod. Because of the complexity of the geological conditions of coal seam coal seam drilling engineering drilling is more complicated than others, in the process of drilling bit will encounter with the geological rock in coal seam, it will lead to the drill pipe drilling direction deviating from the expected trajectory direction, namely drill pipe bend in the coal hole drilling, hole will form fulcrum and drill pipe similar form of "pendulum" movement, this kind of games cause drill pipe and coal wall of hole intense multipoint contact friction collision occurs. Figure 1 shows the finite element model of the borehole wall of the drill pipe.

Figure 1. Finite element model of drill pipe and coal hole wall

The impact of the drill pipe and the coal hole wall is very short, which is completed in a few tens of milliseconds. The impact force caused by the impact is the main cause of the failure of the coal hole wall. From a large number of drilling operations found in some of the phenomena and the experimental results obtained can be found, in the drill pipe and the hole wall of the collision process in the drill pipe joints and the hole wall of the collision is the most [13-14]. Following the Lagrangian method as the theoretical guidance, the collision between drill pipe and coal wall is studied, and the nonlinear dynamic characteristics of the impact force of drill pipe are analyzed under the condition of the change of the diameter of the coal hole.

3. Dynamic Simulation Analysis of Collision between Drill Pipe and Coal Wall

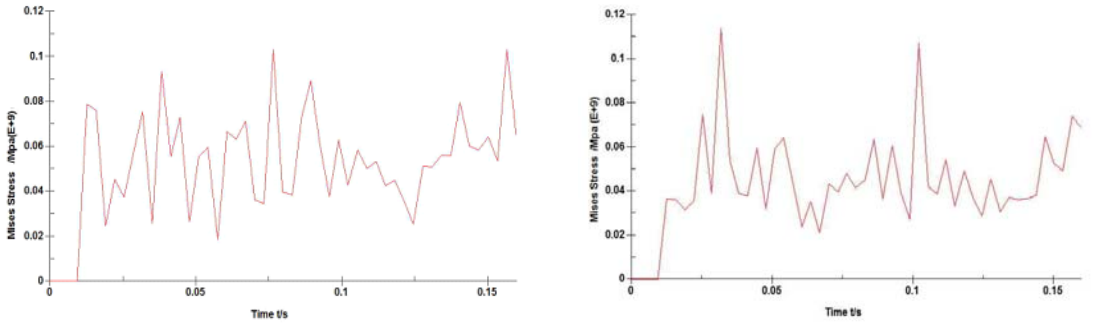
In the course of the collision between the drill pipe and the coal wall, the hole wall is seen as a rigid body and is fixed. At a speed of v=5.36m/s drill (drill rotation speed) along the radial direction of coal hole wall impact coal wall.According to the diameter of drill pipe, coal hole wall hole diameter and drill shaft speed computing collision velocity of drill pipe and the hole wall. This paper mainly analyzes the drill pipe in 98 mm, 108 mm, 118 mm and 128 mm coal hole in the pipe at the same point, the stress variation in the different time. Thus revealed collision coal wall of hole drill pipe's influence on the stability of hole wall.



(a) (b)

Figure 2. Stress analysis of the 98mm pore wall coal drill pipe and hole wall collision

In figure 2, the figure (a) and (b) is drill pipe in the coal with a diameter of 98 mm hole collision wall under the action of stress distribution of different time, the initial conditions for drill pipe rotation of linear velocity of 5.36 m/s collision with the coal wall in the radial direction. In the first to break the coal in the process of drilling bit can produce a lot of broken coal in the coal hole clearance, drill pipe and coal hole wall in the process of collision breaking these coal further squeeze, along with the high pressure air flow of pump station to provide discharge hole, in the process, as a result of the drill pipe drilling speed faster, drill pipe drilling pressure is bigger. In the drill rod elastic deformation energy and mutual superposition of vibration wave by drill pipe vibration (stress), under the joint action of collision with the hole wall, the stress changes as shown in figure 2. Impose after initial conditions on drill pipe, drill pipe and coal hole wall along the radial direction is touch, at time t = 0.0098 s, drill pipe and coal wall of hole collision stress value increase rapidly to 89Mpa, the stress of drill pipe in the subsequent time increases unceasingly, at time t = 0.0735 s stress value reached 220Mpa. From the above analysis result, the drill string collision wall of hole of time is very short, the collision of drill pipe produced by stress value is large, the reason is because the small coal hole clearance, high drilling rate and drilling pressure is bigger, drill pipe bending deformation of the elastic energy is absorbed by drill pipe and the hole wall.



(c) (d)

Figure 3. Stress analysis of the 108mm pore wall coal drill pipe and hole wall collision

In Figure 3, figure (c) and (d) is the drill pipe under with a diameter of 108mm coal hole wall collision effects at different times of stress distribution and initial conditions for drill rod rotating movement of line speed is 5.36m/s in the radial direction and the coal wall collision. In the drilling process of drill pipe, drill broken coal and guide the drilling, in normal drilling conditions, the coal hole diameter should is slightly larger than the diameter drill bit, drill pipe and the coal hole of the annular space is not large, but in front of the drill pipe vibration analysis shows that, the drill pipe vibration of elastic deformation and drilling pressure under the combined action of drill pipe and the coal hole wall contact occurs. The stress generated by the

collision is shown in Figure 4. The drill rod is applied initial conditions, in the collision of the drill rod of this period of time t=0s ~ 0.071s, drill pipe along the coal hole diameter and hole wall collision, the drill pipe in this period of time should force value gradually increased from 0 to 80MPa. The drill pipe in t=0.0113s when the state of freedom of movement to the bending deformation and pore wall collision of the equivalent stress increased rapidly to 38MPa. From coal and rock mechanics research know, coal rock is a kind of brittle hard materials, no water dry coal seam drilling process, the drill bit to drill through the coal experience has a lot of fractured zone (broken region), where the coal experience is very unstable, with the violent vibration of the drill pipe, coal began to collapse, pipe extrusion pressure under the action of coal particles becomes broken exhaust hole coal. At this time coal hole diameter further increases. From the drill pipe and coal hole wall contact collision during this period, when reach maximum contact stress, the equivalent stress value and reduce soon, this is because in the event of a severe vibration reduces the drilling rate, while its impact stress drops rapidly, the drill operators depending on the situation will be repeated back to drill, to reduce the violent vibration and impact.

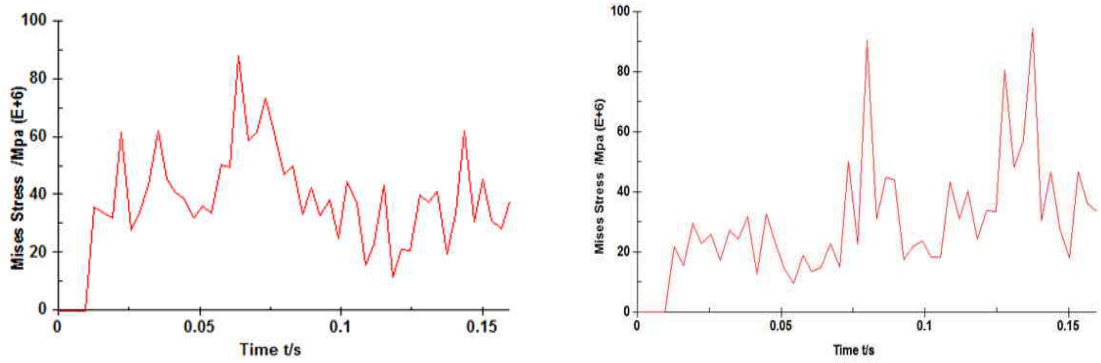
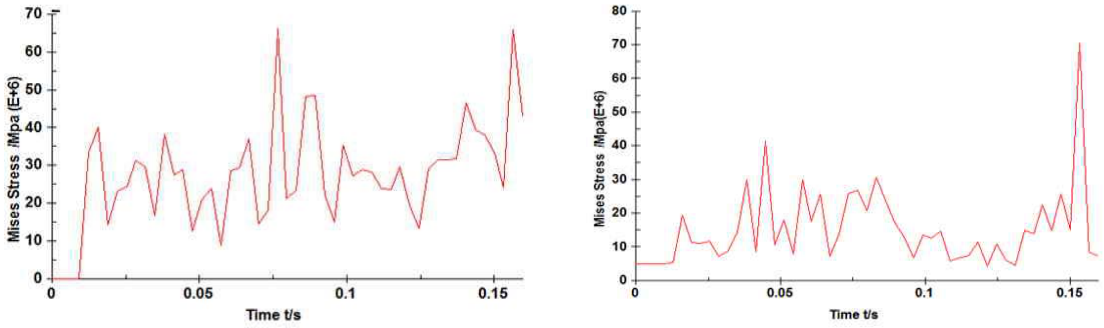


Figure 4. Impact stress of drilling pipe and coal hole wall under the condition of 118mm

Drill pipe under with a diameter of 118mm coal hole wall collision effects at different times of stress distribution, because the diameter of the hole wall increases so the drill pipe and the coal hole wall in the radial direction on the collision velocity is reduced to 3.58m/s in Figure 4 Diagram e and f. From applying initial conditions and to the drill pipe and the coal hole wall collision of this period of time t=0s ~ 0.0121s, drill pipe along the diameter direction of the coal hole uniform motion. At this time the contacts should be force to 0. In time t=0.0123s. Due to the collision contact drill pipe and the wall of the coal hole, at the collision point should force increases rapidly and at the point of contact stress quickly reached 38Mpa. After the collision of the drill pipe and the coal hole wall 0.0539s time of drill pipe should force reaches the maximum value of 89.6MPa. From the above analysis, it can be known that the stress change of drill pipe and the collision speed is a nonlinear relationship. From within the contact impact of drill pipe and the coal hole wall of this period of time, when the contact stress reached a maximum value, and then, the equivalent stress value and decreases quickly. This is because most of the energy was absorbed coal borehole wall and drill pipe.



(g) (h)

Figure 5. Impact stress of drilling pipe and coal hole wall under the condition of 128mm

In the drill pipe and the coal hole wall continuous collision process, coal continuously from the coal hole wall stripping down the drill pipe and the coal hole wall of the annular space is more and more big, at this point, the drill pipe because of its vibration over speed makes the hole drilling rig drilling speed is lowered, the drill pipe bending elastic deformation can be decreased as well. As shown in Figure 5, when the pore size is 128mm, the stress values are significantly lower than those of the first three. After applying the initial conditions, we obtain the maximum stress value of 74Mpa and 76Mpa. With drill pipe stress value decreases gradually, the pipe burst failure and fatigue fracture phenomenon will decrease. In this case the stability of hole wall is very helpful, is beneficial to the gas drainage drilling process smoothly.

In order to more clearly with the force of the increase of the coal hole diameter the drill pipe, we will drill pipe with diameter change of stress change data list, as shown in Table 1, and draw the graph, as shown in Figure 6.

Table 1. Change of stress of drill pipe

Coal hole diameter(mm)	83	88	93	98	103	108	113	118	123	128	133
Maximum stress of drill pipe (Mpa)	307	271	253	243	189	117	106	94	82	76	43

The curve can be seen from Figure 6, the stress value of drill pipe is obviously decreased with the change of the diameter of coal hole. That in the small coal hole diameter, drill pipe and the coal hole wall contact should force is larger, with the gradual expansion of the coal hole diameter, drill pipe contact stress is reduced gradually, and gradually become more stable state.

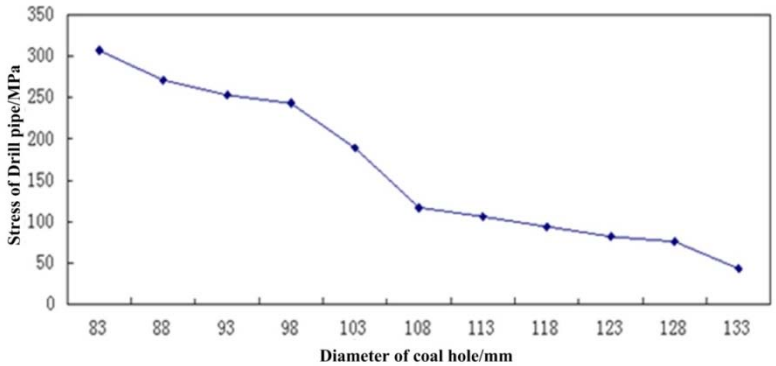


Figure 6. Maximum stress change curve of drill pipe with diameter of coal hole

Through the impact in different aperture of drill pipe stress analysis shows that the coal hole diameter by 83mm increased to 133mm, drill pipe and the wall of the hole coal maximum impact stress by the value of the reduced to the 43Mpa. This is because in the initial drilling process of the drill rod stress state from unstable to stable, contact impact stress reduction can effectively reduce the fatigue damage of drill pipe which are caused by the collision. At the same time, the decrease of the contact stress of the drill pipe is also beneficial to maintain the stability of the hole wall.

4. Conclusion

Taking into account due to the drill pipe and the coal hole wall of the contact collision, according to dynamics is widely used in the central difference method, combined with the collision process of drill pipe drill pipe is constructed by the force of the collision boundary conditions, using the commercial software ANSYS dynamic module of LS-DYNA to drill pipe and the coal hole wall touch hit and loading process is simulated and analyzed, in a certain extent can instead of the actual experiment, reduce test cost and improve the efficiency of scientific research.

Found in the analysis of the process of collision is lead to instability of the hole wall of the main reasons, the drill pipe and the coal hole wall collision makes the degree of bending deformation of the drill rod increase, also make the vibration phenomenon also more intense collision analysis process is more complicated. The collision energy wave (i.e. stress wave) by the drill pipe and the coal body part or all of the absorption, which is drill pipe limitation of fatigue, fracture and hole wall collapse, collapse hole and pipe sticking phenomenon the important reason.

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