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Influence of Coal Rock Hardness and Confining Pressure on load Fluctuation Characteristics of PDC bit during Gas Extraction Borehole in Soft Coal Seam

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Abstract**—** *Load fluctuation characteristics have a great influence on drilling performance. so, study the influence of coal rock hardness and confining pressure on the load fluctuation characteristics of PDC bitbecome more and more important. Gas drainage drilling experiment table was built and Gas drainage drilling experiment was carried out under different coal rock hardness and confining pressure.The results indicate that drilling torque and feed resistance are decreased with the increase ofcoal rock hardness. Vibration amplitude of drilling torque and feed resistance increase with increase of coal rock hardness when the value of coal rock hardnessis larger than 1.3. Vibration amplitude of feed resistance is maximumwhen the value of coal rock hardness is 1.03 and Vibration amplitude of feed resistance is minimum when the value of coal rock hardness is 1.03. Drilling torque and feed resistance are increased with the increase of confining pressure. Vibration amplitude of feed resistance decreases from 3MPa to 7MPa then increases. Vibration amplitude of drilling torque and feed resistance are all minimum when the value of confining pressure is 7MPa. It provides a good basis for setting the appropriate feeding speed and rotation speed in actual work.*

Keywords— coal rock hardness, PDC, borehole.

I. INTRODUCTION

All metallurgical and mechanical aspects of failure that can occur for a drill pipeare considered and discussed. And finally, this comprehensive review leads to a conclusion that categorizes the primary sources of drill pipe failure into seven major groups and makes some recommendations to avoid them[1].The ANASYS software was applied to analyze the inherent frequencies of the vertical vibration, horizontal vibration and rotary vibration during the different drilling depth. The excitation frequency to the drilling rod could be changed by the rotary speed adjusted at drilling rig working period. Thus the resonance caused by the vibration could be reduced and could provide the guidance to the success of the geological exploration[2].Transverse vibrations of drillstrings caused by axial loading and impact with the wellbore wall is studied[3].A linear quadratic regulator (LQR) controller is designed based on a linearized model and is shown to be effective in eliminating this type of oscillations. It is also shown that for some operational parameters the control action may excite large bending vibrations due to coupling with the torsional motion[4].With an increase in borehole pressure, the side crack length decrease significantly; furthermore, the main mode of rock failure shifts from tension to shear[5].The fractal dimension of cracks in the coal seam roofing is affected by the thickness of coal seam, spacing of coal seam and the lithological characteristics of overlying rock strata. With the increase of the thickness of coal seam (composite thickness of coal seam), the fractal dimension of cracks increases[6].In orderto increase the drilling performer of PDC bit, lots of research have been done, however, papers aboutinfluence of coal rock hardness and confining pressure on the load fluctuation characteristics of PDC bitis few. So drilling experiment table is built andcarried out underdifferent coal rock hardnessand confining pressure. In this paper, influence of coal rock hardness and confining pressure on drill pipe vibration is researched and some conclusions are obtained.

II. DRILLING EXPERIMENT TABLE IS BUILT

2.1Test bench

According to the theory of rock cutting and breaking, the

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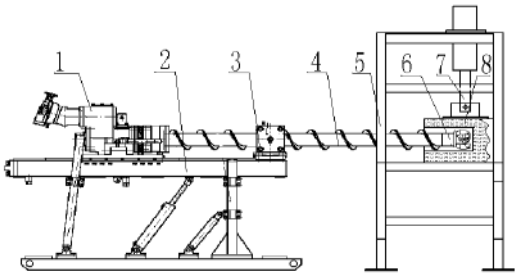
establishment of the gas drainage drilling test bench (Fig1) is built. The test bench mainly has two parts, the power system and the testing system. The test rig drilling experiments is not only used in drilling coal rock with PDC bit ,but also in a variety of types of bits drilling test.

1-fluid cylinder; 2-coal wall support; 3-clamper; 4-advanced gear; 5-gyroscope; 6-control Table; 7-test coal wall; 8-drilling bit; 9-drill pipe; 10-flow sensor; 11-pressure pickup; 12-data acquisition; 13-display interface; 14-flow digital display meter; 15-draught fan



1-clinostat ; 2-feeding device ; 3-clamping device ; 4-drill pipe ; 5-coal wall support ; 6-PDC bit ; 7-hydraulic cylinder ; 8-test coal wall Fig .1. Gas drainage drilling experiment table

2.1.1Power system

The dynamic system of the test bench adopts ZDY1900S full hydraulic drilling machine. The rig is mainly composed of a host machine, pumping station and control station. Pump station is driven by the motor rotation, the hydraulic oil will be transferred to the feed passage and the rotary actuator, the control console on the pole realizes the drill rotation and feed. The drilling machine not only provides power for the drilling tool, but also provides the confining pressure load for the confining pressure loading device on the top of the coal wall support. At the top of the coal wall support, HSG90/63 engineering hydraulic cylinder is provided, the rated working pressure of the hydraulic cylinder is 16MPa, and the stroke is 640mm, so as to meet the requirement of applying the confining pressure to the coal wall. The hydraulic circuit of the hydraulic circuit is additionallyprovided with two-way hydraulic lock, so as to ensure the stablity of the confining pressure in the operation of the hydraulic cylinder.

2.1.2 Test system

YSV dynamic signal acquisition and analysis software were used in testing system for drilling test data acquisition system; FST800-201G222A-16B pressure sensors are arranged in the hydraulic motor and hydraulic cylinder oil import to drill drilling torque to tests the feed resistance signal. The main performance parameters of the sensor: range: 0-31.5Mpa; sensitivity: 158.73 output voltage: 0-5V; standard engineering unit: mv/Mpa; measurement accuracy: 0.5%FS; the flow of the hydraulic system using the model for the turbine flow sensor LWGY-15A, the nominal pressure 6.4MPa, maximum pressure loss is 0.0035MPa, the turbine flow sensor and the hydraulic motor return oil pressure sensor on the pipeline in series.According to the above power system and the test system composed of drilling test bench, provide the maximum torque of 1900Nm and maximum speed of 300r / min, to the process of 600mm. According to the working performance of the drilling rig, the displacement of the main oil pump in the pump station is changed to change the rotating speed of the drilling machine. The speed range of the drill bit is 85-300r/min. Adjust the displacement of the auxiliary oil

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pump in the pump station to change the feed rate of the drilling mechanism. The feed rate range of drilling mechanism is 0-3m/min.

III. INFLUENCE OF COAL ROCK HARDNESS AND CONFINING PRESSURE ON LOAD FLUCTUATION CHARACTERISTICS

3.1 Influence of coal rock hardness on load fluctuation characteristics

To research the influence ofcoal rock hardness（f） on load fluctuation, drilling coal rock experiment is carried out under different coal rock hardness(f=0.65, 1.03, 1.3, 2.4, 3.24). Working condition parameters in the process of drilling coal rock are as follows: confining pressure is 7MPa, feed speed is 0.5 m/min, rake angle of PDC bit is 10 °，rotation speed is 190r/min. Feeding resistance and drilling torque is got under different rotation speed is shown in table1.Fig.2 and Fig.3 show influence of rotation speed on load fluctuation characteristics.

Table1:*Drilling torque and feeding resistance under different coal rock hardness*

Coal rock hardness （f）	Drilling torque (N·m)			Feeding resistance(KN)		
	Maximum value(N·m)	average value(N·m)	standard deviation	Maximum value(KN)	average value(KN)	standard deviation
0.65	370.7	353.2	18.7	3.9	3.2	0.39
1.03	378.4	364.7	11.6	4.9	4.0	0.65
1.3	417.2	385.5	19.2	4.9	4.8	0.27
2.4	428.6	400.3	21.5	5.3	5.0	0.33
3.24	459.7	420.1	24.8	5.9	5.2	0.53

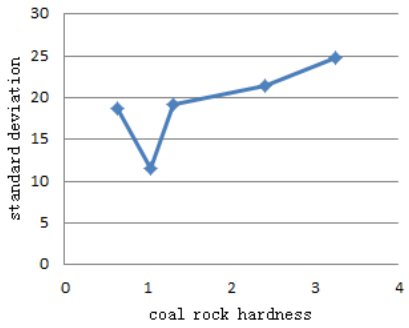

Fig.2: Influence of coal rock hardness ondrilling torque's load fluctuation characteristics

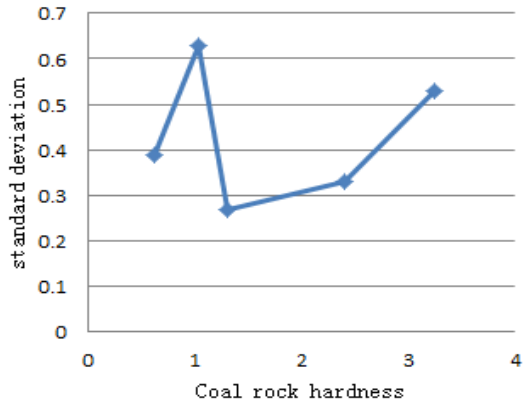

Fig.3: Influence of coal rock hardness on feeding resistance's load fluctuation characteristics

Table 1 , Fig1 and Fig2showthat drilling torque and feed resistance are decreased with the increase ofcoal rock hardness. Vibration amplitude of drilling torque and feed resistanceincrease with increase of coal rock hardness when the value of coal rock hardnessis larger than 1.3. Vibration amplitude of feed resistance is Maximum value when the value of coal rock hardness is 1.03and Vibration amplitude of feed resistance is Minimum value when the value of coal rock hardness is 1.03.

3.2 Influence of confining pressure on load fluctuation characteristics

To research the influence ofconfining pressure on load fluctuation, drilling coal rock experiment is carried out under different confining pressure (3MPa, 5MPa, 7MPa, 9MPa). Working condition parameters in the process of drilling coal rock are as follows: feed speed is 0.7 m/min, rake angle of PDC bit is 10 °，rotation speed is 190r/min. Feeding resistance and drilling torque is got under different rotation speed is shown in table1.Fig.3 and Fig.4 show influence of rotation speed on load fluctuation characteristics.

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Table2:*Drilling torque and feeding resistance under differentconfining pressure*

confining pressure （MPa）	Drilling torque(N·m)			Feeding resistance(KN)		
	Maximum value(N·m)	**average value(N·m)**	**standard deviation**	**Maximum value(KN)**	**average value(KN)**	**standard deviation**
3	335.8	317.2	13.5	3.16	2.50	0.48
5	398.9	351.8	15.9	4.04	3.45	0.42
7	400.1	366.1	12.8	4.61	3.93	0.39
9	422.1	375.3	21.1	5.56	4.74	0.48

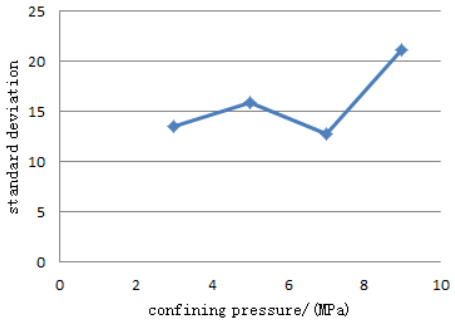

Fig.3(a): Influence of confining pressure ondrilling torque's load fluctuation characteristics

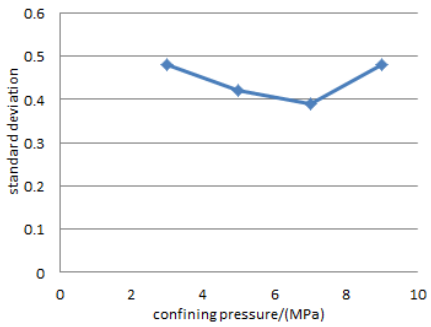

Fig.4: Influence of confining pressure onfeeding resistance's load fluctuation characteristics

Table 2 , Fig3 and Fig4showdrilling torque and feed resistance are increased with the increase of confining pressure. Vibration amplitude of feed resistance decreases from 3MPa to 7MPa then increases. Vibration amplitude of drilling torqueand feed resistanceareall minimum when the value of confining pressure is 7MPa.

IV. CONCLUSIONS

Drilling torque and feed resistance are decreased with the increase ofcoal rock hardness. Vibration amplitude of drilling torque and feed resistanceincrease with increase of coal rock hardness when the value of coal rock hardnessis larger than 1.3. Vibration amplitude of feed resistance is Maximum value when the value of coal rock hardness is 1.03and Vibration amplitude of feed resistance is Minimum value when the value of coal rock hardness is 1.03.Drilling torque and feed resistance are increased with the increase of confining pressure. Vibration amplitude of feed resistance decreases from 3MPa to 7MPa then increases. Vibration amplitude of drilling torqueand feed resistanceareall minimum when the value of confining pressure is 7MPa. In the paper, vibration amplitude of drilling torque and feed resistance was researched, but many forms of vibration include torsional vibration, longitudinal vibration and lateral vibration during drilling drills coal rock, study these forms is next important task.

V. ACKNOWLEDGEMENTS

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