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Design and Research of Electromagnetic Drive Pulley Type Downhole Blowout Preventer

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Abstract. A new electromagnetic drive rope and pulley type downhole blowout preventer is proposed. The moment equilibrium equation of downhole blowout preventer is established. The structural dimensions of the valve plate connecting position of blowout preventer and pulley rope location are optimized. The dynamic simulation of pulley type downhole blowout preventer is carried out to improve the parameters of this new blowout preventer and to improve its motion performance and mechanical properties.

0 Introduction

Downhole blowout preventer has good sealing performance, which can meet the work requirements of whole-process underbalanced drilling state in the process of oil and gas mining, and can better isolate downhole pressure in the working process to reduce the operational risk of being forced to trip with pressure in the process of drilling and completion[1~2]. But in the domestic market, the downhole blowout preventer is mainly dependent on imports, and its key technologies have been monopolized by foreign[3~5]. Therefore, it is significant to improve the technical level of downhole blowout preventer and to develop the new downhole blowout preventer with independent core technology.

1 Structural Design of the New downhole Blowout Preventer

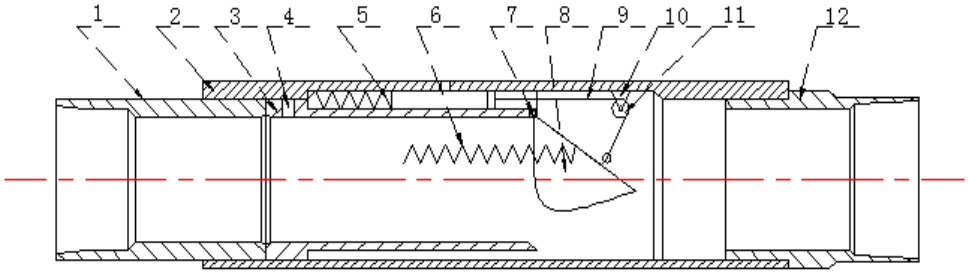
(1) Structural Comparison of the downhole Blowout Preventer

There are two main types downhole blowout preventer at home and abroad: One is that the hydraulic driving force is provided by the ground control system. Then, through the hydraulic lines or other intermediate connection parts, the inner sleeve inside the blowout preventer is moved up and down and the valve plate of downhole blowout preventer is controlled to achieve open or close the valve plate. Another is that the hydraulic driving force is provided by the ground control system, but the mechanical mechanism in the tank of the blowout preventer outer tube is driven, and the mechanism impacts on the valve plate directly to achieve open or close the valve plate.

In field applications, These two downhole blowout preventers completed the whole-process of underbalanced drilling and completion operations and achieved good results. But there are also some issues, such as hydraulic system leak, low efficiency, and it can not fully achieve the whole-process of underbalanced and the depth into the well is limited by pipeline.

(2) The design of electromagnetic drive pulley type downhole blowout preventer

Through studying and summarizing the technical characteristics of downhole blowout preventer and existing mechanical structures and solutions, one new electromagnetic drive pulley type downhole blowout preventer is raised. The overall structure is shown in Figure 1. It is composed by the top connector, outer tube, body, pin, valve plate, pulley, rope, tension spring, lower connector, and the electromagnetic drive system, control system. The program design is characterized



1-top connector; 2-outer tube; 3- body; 4-proximity switch; 5-electromagnetic driving equipment; 6-tension spring; 7-pin; 8-valve plate; 9-rope; 10-support shaft; 11-pulley; 12-lower connector

Fig.1 Structure of electromagnetic drive pulley type downhole blowout preventer

in that the electromagnetic drive system is composed by the electromagnetic driving equipment, rope, support shaft and pulley. Wherein electromagnetic driving equipment is fixed to outer tube by the screw; the rope is connected to the rod in the electromagnetic equipment; the support shaft is fixed to the inner wall of the outer tube; the pulley is stalled to the support shaft; the other end of the rope is connected to the other end of the valve plate through the pulley. Electrical control system is composed by the proximity switches, wire and the controller. The proximity switches is stalled to upper half of the body. Terminal of the proximity switch is connected to the control system and controller to send signals to the electromagnetic driving equipment through wire.

Working principle: During the drilling process, when the drill string or pipe contacts to the valve plate of downhole blowout preventer, opens it. The proximity switches of downhole blowout preventer send signals to the ground control system through wire. Then, the ground control system send signals to let the electromagnetic driving equipment electrify; the rod in the electromagnetic equipment moves up under the attraction of the electromagnet. Then, the valve plate is fully opened by rope to make drill drilling through the downhole blowout preventer. when the drill pulls out of the hole, drill moves up while contacting to the proximity switch position, the proximity switch sends signals to the ground control system through wire. Then, the ground control system sends signals to let the electromagnetic driving equipment power cut, and meanwhile rope loses tension, valve plate is closed under the tension of tension spring. Figure 2 shows the open structure of electromagnetic drive pulley type downhole blowout preventer.

2 Study of size parameter of new downhole blowout preventer

The solution process of the pulling force provided by the rope: First determine the position of the junction of the rope and the valve plate and the position of the support shaft which is used to supporting pulley, That is, to determine the size of the x_2 and x_3; Then, according to the size of x_2 and x_3 to determine the pulling force. the relation between parameters α and β and the relation between x_2 and x_3 are closely related. Therefore, it needs to first determine the relation between x_2 and x_3. There are three different situations: $x_2 > x_3$, $x_2 = x_3$, $x_2 < x_3$. These three situations are analyzed to figure out the maximum tension provided by the rope in different circumstances and to be compared. Then, the minimum pulling force is selected to be carried out the optimization calculation.

From the comparing of the three situations' calculation of $x_2 > x_3$, $x_2 = x_3$, $x_2 < x_3$, when $x_2 = x_3$, the pulling force provided by the rope is the minium. Therefore it is the most reasonable that the relation between x_2 and x_3 is designed to $x_2 = x_3$.

3 Modeling and simulation analysis of new downhole blowout preventer

(1) The establishment of simulation model

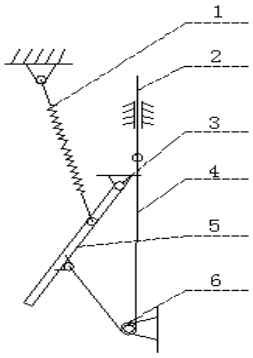
PRO/E was used to establish the 3D model in this paper. Modeling of downhole blowout preventer is composed by five main parts: body and outer tube of blowout preventer, blowout preventer value plate, pulley and support shaft, electromagnetic equipment and rope, which are modeled respectively[6-7].

Physical model can be formed by adding constraints and forces to the geometric model. Kinematics simulation can be performed and the virtual prototype model can be established through defining the relation between the kinematic pairs[8].

(2) Motion simulation analysis of blowout preventer equipment

After the success of model validation, the simulation and research of the downhole blowout preventer are carried out.

According to the simulation analyzing graph, the change of angular velocity and angular acceleration of valve plate's centroid with time, and the change of the displacement in the Z-axis direction of valve plate's centroid, are shown in figure 3,4,5.



1-tension spring; 2-rod; 3-pin; 4-rope; 5-valve plate; 6-pulley

Fig.2 Open structure of electromagnetic drive pulley type downhole blowout preventer

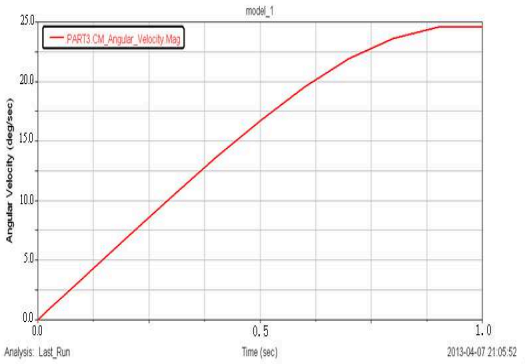


Fig.3 The change of angular velocity of valve plate's centroid with time

As is shown in figure 3: angular velocity is 0 when blowout preventer valve plate in the initial position, increasing gradually with time. Because in this process, the tension on the rope is the constant tension provided for the electromagnetic equipment, and during the process of valve plate opened, the force required is increasing gradually, which is the process that the angle β ranges from 90° to 0°. What's more, The difference between the torque tension of rope on the valve plate and the torque tension of the tension spring on the valve plate is reducing in the process of valve plate opened. Therefore, angular velocity of valve plate is increasing gradually with time. Meanwhile, angular acceleration of valve plate is decreasing gradually with time, so is the angular acceleration of the centroid. when the valve plate will be fully opened, it is closed to zero, just as shown in figure 4.

Figure 5 is the change of the coordinate of valve plate's centroid with time. As is shown in the figure, the coordinate in the Z-axis of the valve plate's centroid is increasing, under the action of the

tension of rope. That is, the process of the valve plate opened. In this process, The displacement of the valve plate's centroid in the Z-axis is 86 mm approximately, Substantially equaling to the radius of the valve plate. Therefore, blowout preventer valve plate can be opened successfully under the pulling force, and the time is about 1s. From this, it is verified that the electromagnetic drive pulley type downhole blowout preventer can be opened smoothly in the simulation environment, which verified that the structure sizes of downhole blowout preventer equipment calculated by theory meet the design requirements.

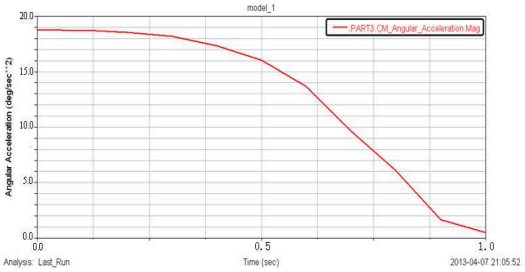


Fig.4 The change of angular acceleration of valve plate's centroid with time

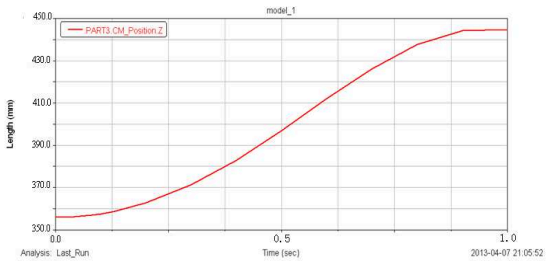


Fig.5 The change of coordinates of valve plate's centroid with time

4 Conclusions

(1) In this paper, one new electromagnetic drive pulley type downhole blowout preventer mechanism is raised, using the electrical control system instead of the original hydraulic control system. And there are the following advantages: simple structure, easy to install, accurate and reliable operation, high degree of automation.

(2) Using the MATLAB toolbox, the structural size optimization of the pulley position and the connection position of the rope on the valve plate is carried out through establishing moment equilibrium equation of the blowout preventer. The optimum structure size program is chosen according to comparative analysis of the results of different scenarios.

(3) Dynamic simulation is carried in the ADAMS/View. According to the problems or errors in the process of simulation analysis, the parameters of the downhole blowout preventer is improved. What's more, the kinematic and mechanical properties of the new downhole blowout preventer are improved.

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