**International Journal of Engineering and Advanced Research Technology (IJEART)**
**ISSN: 2454-9290, Volume-4, Issue-3, March 2018**

# A Preliminary Study on the Motion Simulation of 15,000 - meter Drill Winch Based on AMESim

**Qiang Fan, Song Tao Jiu, Peng Yu Li, Guo Jing Gui**

***Abstract*— According to the development trend and requirement of the current drilling machine winch, the lifting simulation model of the 15000 m drilling machine winch system was established by using AMESim motion simulation software with 15000 m drilling machine winch as the research object. This paper analyzes the different working conditions of the winch static balance, the normal lifting, the constant braking stage, the emergency braking and the emergency braking stage, and obtains the movement characteristics of the system under different working conditions, and then obtains the different working conditions The maximum force of the wire rope and the dynamic load coefficient of the system. The simulation results have a certain reference value for the design of 15000 m drill winch.**

***Index Terms*— drill winch; lifting system; motion simulation; dynamic load factor**

## I. INTRODUCTION

Drill winch is an important part of the drilling machinery. During the entire drilling process, it is required the drill winch to up and down drilling tools, running casing, adjust the drilling pressure, suspension of static drilling tools, drilling tools, lifting weights and other auxiliary work in wellsite. During the actual operation of the winch, due to the presence of the flexible body steel wire rope and the inertia of the system-related components, the winch system will generate a large impact and vibration when lifting. These shocks and vibrations have a great impact on the normal work of the winch. Therefore, it is very necessary to develop the simulation of the winch motion [1].

In recent years, with the increasing demand for fossil fuels, the extraction of shallow, medium and deep oil and gas wells has been unable to meet the energy needs of the entire society. With the development and maturation of various new technologies, global oil and gas resources exploitation has shown a tendency to develop in areas that could not be reached due to technical limitations, such as deep seas, deep land layers and even super deep layers. While China needs to import a large amount of oil and gas resources each year, the oil and gas resources in the deep, ultra-deep and deep sea areas of China cannot be effectively exploited and utilized. For this reason, as early as 2010, China published the relevant technical parameters and standards for 15,000 meters of rig winches [2]. However, there are no mature and practical 15,000 meters of rig winches in domestic drilling rig equipment. Therefore, research is conducted on rig winches that have a nominal drilling depth of up to 15,000 meters, to achieve breakthroughs in China's land deep, ultra-deep and deep-sea oil and gas resources, and thus to achieve the goal of replacing China's oil resources. In line with the current development trend of rig winches and the domestic drilling industry's demand for higher performance drilling equipment [3].

The study of kinematics problems usually has two methods, experimental and theoretical calculations [4]. However, the former is time consuming and costly, while the latter is difficult to solve and has low accuracy. AMESim motion simulation software can overcome the shortcomings of the above two methods. therefore, This paper uses the AMESim motion simulation software to simulate and analyze the 15,000-meter rig winch based on the basic parameters of the 15000-meter rig winch specified by relevant national standards and industry standards.

## II. ESTABLISHMENT OF A MOVEMENT SIMULATION MODEL

AMESim is one of the most commonly used motion simulation software [5]. Has been successfully applied to automobiles, engines, aerospace and petroleum and metallurgy and other heavy equipment, including mechanical, control, fluid, thermal analysis, electromagnetic and energy and other disciplines, have achieved quite satisfactory results. In order to facilitate the establishment of the model and the simulation, the following assumptions and simplifications were made in this paper when using AMESim to establish a simulation model for the hoisting system of a 15,000-meter drill winch:

(1) Ignore the slippage between the wire rope and the pulley in the lifting system and ignore the energy loss on the wire rope;
(2) only consider the vertical vibration of the system and ignore its horizontal vibration;
(3) Since the derrick stiffness coefficient is much larger than steel wire ropes, the derrick is considered to be rigid, ignoring the influence of the derrick;
(4) Ignore the elasticity of the drill string and treat it as a general weight load;
(5) Ignoring the friction between the borehole wall and the drill string and the buoyancy effect of the drilling fluid on the drill string;
(6) Suppose the dynamic load on the fast rope, the travel rope, and the dead rope is equal.
(7) Under the premise of assuring that the lifting characteristics of the drill string and the pulling force of the fast rope are not changed, the pulley system of the system swimming system is simplified to a 1×2 pulley block.

According to the simplification process, a motion simulation model of the hoisting system of a 15,000-meter drill winch is established, as shown in FIG. 1 .

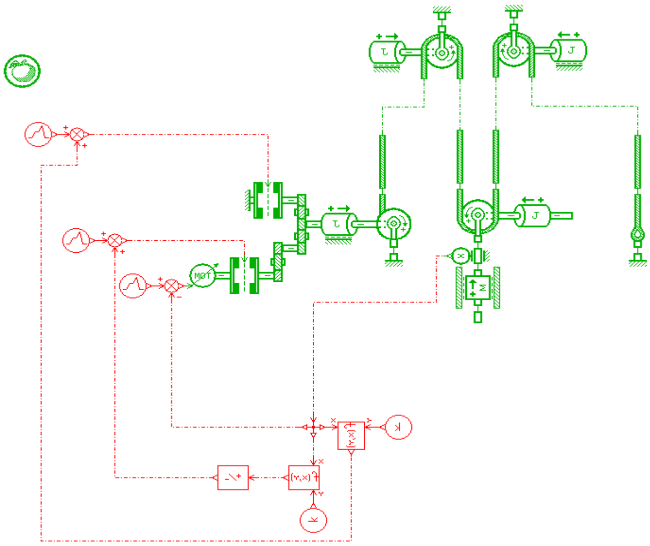

Fig.1 Winch hoisting system simulation model

## III. SIMULATION AND RESULTS ANALYSIS

The simulation model was established. The wire rope of type 6×37S+IWR[2,6-7] was selected as the wire rope for the winch. The relevant simulation parameters were converted according to the simplified method of the winch system and input to the simulation software to statically balance the 15000-meter drill winch. Simulation, winch normal lift simulation, emergency braking simulation of winch constant speed lifting, and emergency braking simulation of winch acceleration and lifting [6-12].

### *A. Static Balance Simulation*

In the actual work of winch, due to the presence of load, the wire rope will be in a taut state. Even if it is hovering, it will be braked by the brake system to suspend the weight of the drill string. Otherwise, the huge self weight from the drill string will play a role. The drill bit will crush the drill bit, causing serious drilling accidents. In the computer simulation, there is a gap between the models and the rope is in a relaxed state. Therefore, in order to avoid causing a large impact and dynamic load, the true situation of lifting of the winch lifting system is simulated as accurately as possible. We need to do a static equilibrium solution.

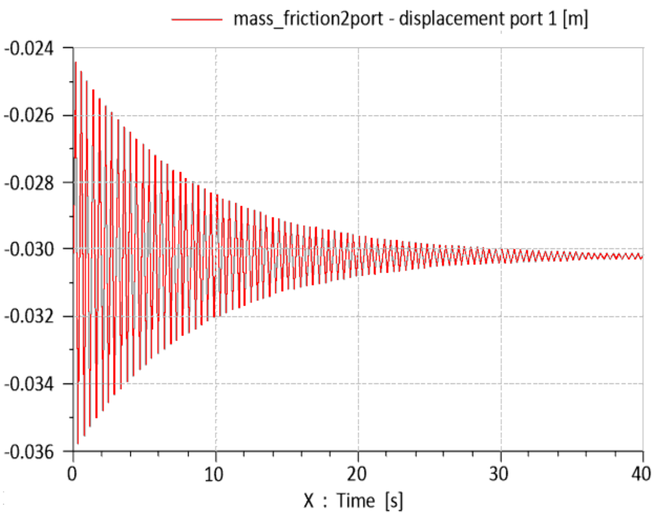


Fig. 2 Load Displacement Curve of Static Equilibrium Process

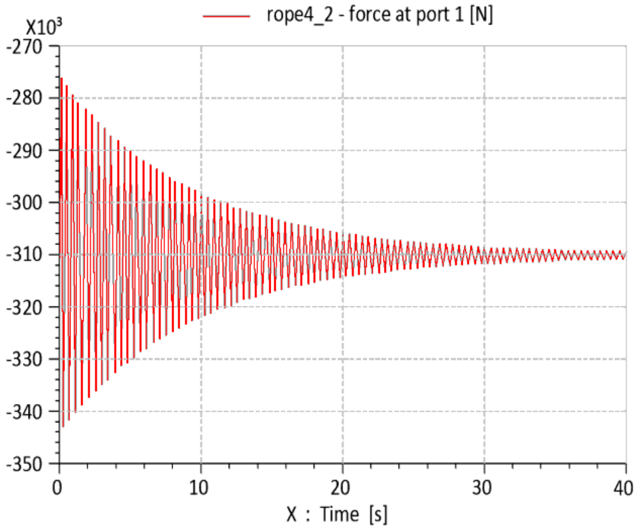


Fig. 3 Rope Force Curve of Static Equilibrium Process

From the simulation results, we can see that at the beginning of the simulation, the load displacement and the tension of the steel wire rope fluctuate greatly. Then, due to the existence of system damping, the fluctuation gradually decreases. Finally, the load displacement is stable at -0.0301m, and the maximum tension of the wire rope is -343.1KN, and finally stabilized at -310.6KN, this value is similar to the wire rope tension under the condition of maximum drill string weight regardless of system efficiency, and the simulation results have reference value.

### *B. Simulation analysis of hoisting process of winch system*

The winch system is a process of acceleration, then uniform speed, and finally deceleration. When lifting, it is only necessary to raise the length of one standing leg. The lifting distance of the setting system in the simulation is more than 27m, but it cannot exceed 28m.

Simulation flow: Start by loosening the clutch and closing the brake. After 2s, the clutch is closed, the brake system is released, and the winch starts to run. When the displacement of the drill string load reaches a certain value, the displacement sensor under the drill string load will feedback and decelerate the winch system until the simulation is completed. From this, we can draw the following simulation results.

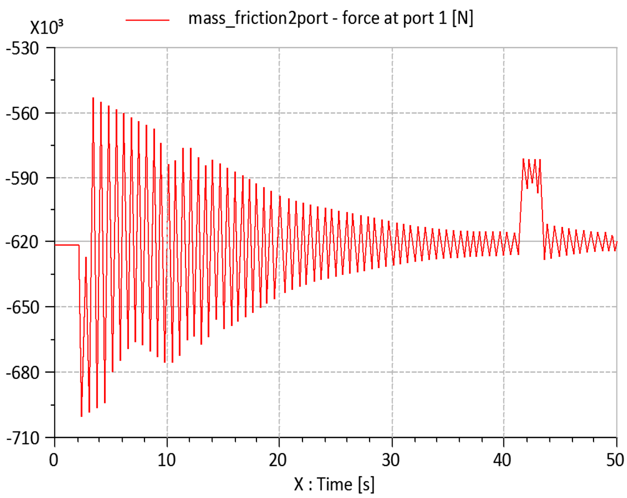


Figure 4 big hook force curve

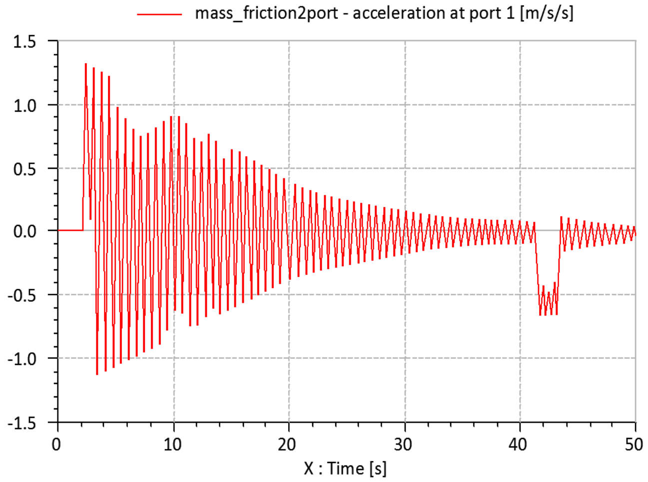


Figure 5 Drill column acceleration curve

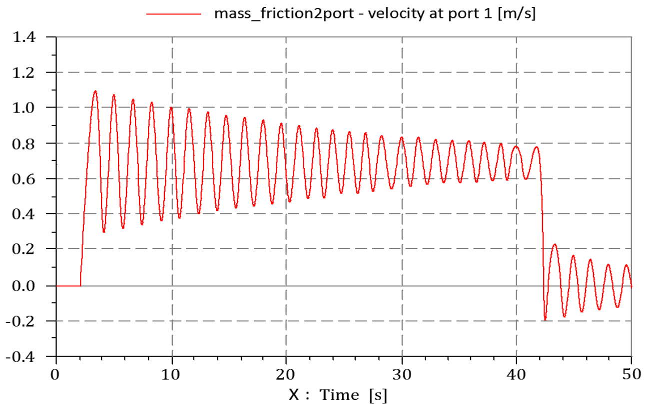


Figure 6 Drilling column lifting speed curve

From the simulation results, it can be seen that after the simulation started, the acceleration value of the drill string fluctuates violently and is positive, the highest value reaches 1.31m/s2, and the drill string is in an acceleration and ascending stage. At this time, the force of the steel wire rope reaches its maximum The value of -700.3KN; then the force of the wire rope on the drill string gradually stabilized at -621.6KN, the acceleration value of the drill string was affected by the force of the wire rope and gradually stabilized near 0, and the lifting speed of the drill string also gradually stabilized at 0.68m/s. As the simulation progresses, the fluctuation range of the system's big hook force, the fluctuation range of the drill string acceleration, and the fluctuation range of the drill string lifting speed are gradually reduced. Since then, under the influence of the system brakes, the acceleration value has increased and has a negative value. The drill string is in the deceleration phase. After that, the big hook force is gradually stabilized at -621.6KN. The acceleration of the drill string and the speed of the drill string are due to the existence of system damping. Gradually decrease to 0.

To convert it back to the actual winch system, we can see:

The maximum tensile force on the wire rope is:

$$P = \frac{-700.3 \times 8}{16 \times 0.77} = -454.7KN$$

The system dynamic load factor is: $K_q = \frac{-700.3}{-621.3} = 1.13$

*C. Simulation analysis of emergency stop for emergency stop of winch hoist system*

During the work of the winch system, it sometimes encounters conditions that require emergency stop and emergency brake operations. This type of operation can cause abrupt changes in the system movement, resulting in more severe dynamic loads and vibrations than normal operating conditions. Serious damage is caused to the components of the system. Therefore, it is necessary to carry out simulation analysis of the emergency stop emergency conditions of the system.

*a) emergency stop emergency brake*

In the stage of constant speed lifting of the system, an emergency brake signal is applied to the system (in the text, the signal application time point is 20 s), the winch hoisting system is simulated and analyzed, and thus the lifting speed curve and hook force of the drill string can be obtained. Curve, as shown below:

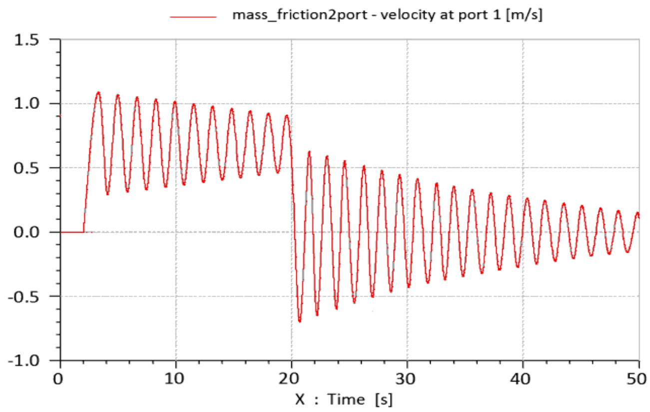


Figure 7 Lifting speed curve of drill string

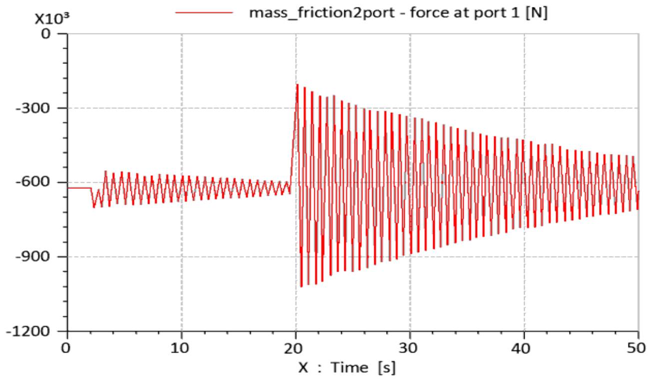


Figure 8 Big hook force curve

From Fig. 7 and Fig. 8, it can be seen that before the emergency braking of the system, the system movement is the same as that of the normal winch of the winch. After the 20s emergency braking, the lifting speed of the drill string is violently fluctuating, and its fluctuation range is -0.70 m/s~ -0.63m/s. As the simulation progresses, the drillstring velocity fluctuations gradually decrease until the end of the simulation. During the period of 0-2s, the force condition of the big hook is basically the same as that of normal lifting of the system. After the emergency braking of the 20s system, the force of the big hook violently fluctuates, and the fluctuation gradually changes from -621.6KN to -621.6KN. The fluctuation ranged from 1020.3 KN to -205.3 KN.

The simulation results converted back to the actual winch system can be seen:

The maximum tensile force on the wire rope is:

$$P = \frac{-1020.3 \times 8}{16 \times 0.77} = -662.5KN$$

The system dynamic load factor is: $K_q = \frac{-1020.3}{-621.3} = 1.64$

b) *Emergency stop emergency stop during acceleration phase*

During the acceleration stage of the system, an emergency brake signal is applied to the system (in the text, the signal application time point is set to 3s). The winch hoisting system is simulated and analyzed, and the lifting speed curve and hook force of the drill string can be obtained. Curve, as shown below:

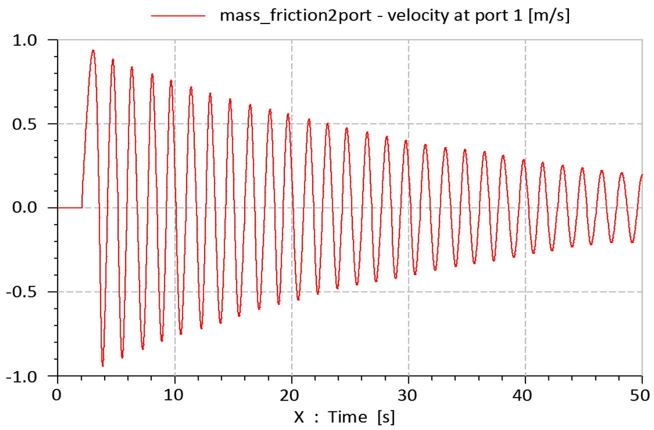


Fig. 9 Drilling column lifting speed curve

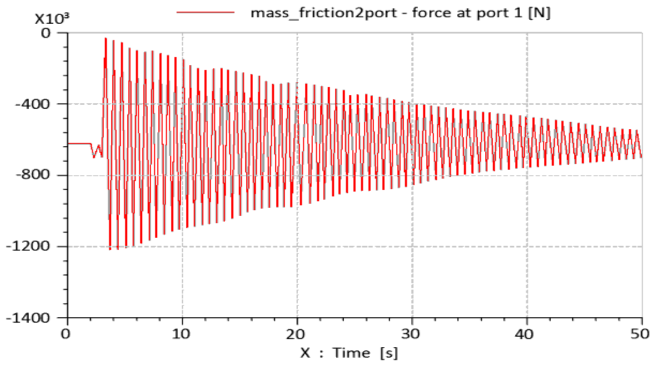


Figure 10 Big hook force curve

From Fig. 9 and Fig. 10, it can be seen that in the interval between 0 and 2 s, the drill string is stationary, and the drill string accelerates from standstill at 2 s. Due to the impact of the system's emergency braking at 3 s, the drill string speed fluctuates violently, with simulations. As a result, the range of drill string speed fluctuations gradually decreased, and the maximum fluctuation range of drill string speed was -0.93m/s to 0.94m/s. After the emergency braking of the system, the force of the big hook increased sharply from -697.9 KN and caused great fluctuations. The maximum fluctuation range was -1218.3 KN to -28.3 KN, and the fluctuation gradually decreased thereafter.

The simulation results converted back to the actual winch system can be seen:

The maximum tensile force on the wire rope is:

$$P = \frac{-1218.3 \times 8}{16 \times 0.77} = -791.1KN$$

The system dynamic load factor is:

$$K_q = \frac{-1218.3}{-621.3} = 1.96$$

After finishing the above simulation results, the following table can be drawn.

Table 1 Stresses of steel wire rope under different working conditions

| Operating conditions | Static balance | Normal rise | Uniform speed emergency brake | Acceleration stage emergency brake | Selected wire rope minimum breaking force |
|---|---|---|---|---|---|
| Wire rope maximum force（KN） | -343.1 | -454.7 | -662.5 | -791.1 | 1890 |

Table 2 Dynamic Load Coefficients of System under Different Working Conditions

| Operating conditions | Static balance | Normal rise | Uniform speed emergency brake | Acceleration stage emergency brake | System dynamic load factor upper limit |
|---|---|---|---|---|---|
| Dynamic load factor | 1.10 | 1.13 | 1.64 | 1.96 | 2.5 |

It can be seen that the maximum force of the wire rope is gradually increased with the static balance of the winch system, normal lifting, emergency braking at the constant speed phase and emergency braking at the acceleration phase, among which the maximum force of the steel wire rope reached -791.1 KN during the emergency braking of the acceleration phase. , is much smaller than the minimum breaking force value of the wire rope; the dynamic load coefficient of the winch system increases gradually with the static balance of the winch system, normal lifting, emergency braking at the constant speed phase and emergency braking at the acceleration phase, among which the acceleration during the emergency braking The maximum load factor is 1.96, which is less than the upper limit value of the system dynamic load factor.

## IV. Conclusion

In this paper, AMESim simulation software was used to model and simulate the hoisting system of a 15,000-meter rig winch, and the simulation results of drill string lifting speed and hook force under different working conditions were obtained. Through the analysis of the simulation results, the following conclusions are drawn:

(1) Due to the presence of flexible bodies such as wire ropes, the speed of the drill string and the force of the big hooks will generate considerable fluctuations during the work of the winch;

(2) The wire rope is under the condition of static balance of the winch, normal lifting, rapid braking at the constant speed stage, and sudden braking at the acceleration stage. Its stress is far less than the minimum breaking force of the selected steel wire rope, but the sudden braking and acceleration phase of the constant speed stage brakes rapidly. Under the two conditions, the force of the steel wire rope can no longer meet the requirements of the safety factor ≥ 3 when the wire ropes used at all levels of the drill rig should maintain the number of drilling ropes and the maximum drill string weight [13]. Therefore, the limit of emergency braking should be avoided as far as possible. Operate, or use other measures to reduce the impact and vibration of the system under these two conditions;

(3) Under the conditions of static balance, normal lift, sudden braking at constant speed stage and sudden braking at acceleration stage, the dynamic load coefficient of the system gradually increases, and the dynamic load coefficient reaches a maximum of 1.96 when the acceleration stage is in emergency braking. The design calls for an upper limit of 2.5 on the dynamic load factor.

REFERENCES

[1] East China Petroleum Institute, Institute of Mining Machinery. Oil drilling and mining machinery [M]. Beijing: Petroleum Industry Press, 1980.06.
[2] SY/T 5532-2010, Oil Rig Winch [S].
[3] Dong Shuwen, Li Tingdong, Gao Rui et al. A review of the international development of deep earth exploration and the status quo in China[J] Geological Journal (English interface),2010,84(6):743-770.
[4] Hou Yongjun, Du Xiaoping. A preliminary study on the dynamics simulation of workover rig lifting system[J].Petroleum Machinery,1998,26(12):4-9.
[5] Fu Yongling, editor. LMS Imagine. Lab AMESim System Modeling and Simulation Example Tutorial [M]. Beijing: Beijing University of Aeronautics and Astronautics Press, 2011.
[6] SY/T 5170-2013, Wire Rope for Oil and Gas Industry [S].
[7] SY/T 6666-2006, Recommended Practice for Selection and Maintenance of Wire Rope for Oil and Gas Industry [S].
[8] Chen Chaoda. Experimental study on the hoisting system dynamics of ZJ45J drilling rig[J].China Petroleum Machinery,1990,18(7):9-14.
[9] Qi Mingxia, Ruan Junfeng et al. Testing and determination of hoisting dynamic load coefficient of workover rig[J]. Petroleum Ore Field Machinery, 1998, 27(2):41-44.
[10] Chen Ruheng. Preliminary analysis of the static and dynamic load tests for the lifting system of 4500 meters rig[J].Acta Petrolei Sinica,1983,4(1):65-78.
[11] Lin Biao. Research on hoisting system of winch for ultra-deep well drilling rig [D]. Jilin University, 2013.
[12] Duan Dehe. Dynamic model and analysis of oil rig lifting system[J].Acta Petrolei Sinica,1989,10(2):94-103.
[13] Chen Ruheng, Shen Jiajun. The design of drilling machinery [M]. Beijing: Petroleum Industry Press, 1995.06.

**Qiang Fan, Song Tao Jiu, Peng Yu Li, Guo Jing Gui,** School of Mechatronic Engineering, Southwest Petroleum University, Chengdu Sichuan 610500