Design of the Hydraulic System for the Rise-fall Device in Power Catwalk

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Abstract. Performance of the hydraulic system for the rise-fall device has a direct impact on the reliability of power catwalk. According to the working principle of the rise-fall device, the scheme design and mechanical models of hydraulic system are established. And test the hydraulic model of the rise-fall device, which is simulated in AMESim software. Finally, field experiment is used to verify the simulation results. The analysis results verify the feasibility of the scheme design of the hydraulic system.

Introduction of the Rise-Fall Device

In petroleum drilling industry, the conveying device of drilling tool known as "the catwalk", is one of the most important equipment in the drilling tool integration system. It is used to implement the transportation of drilling pipes between the ground and the drilling platform. With the development of drilling technology, the automation degree in power catwalk constantly improves and gradually replaces the traditional way of human power in the delivery of drilling pipes [1, 2]. In this paper, hydraulic system of the rise-fall device in a power catwalk is analyzed and studied.

Power catwalk is generally composed of migration device on the ground, the rise-fall device and auxiliary system [3-5]. And the rise-fall device is mainly used to transport drill pipes in the lifting slipway.
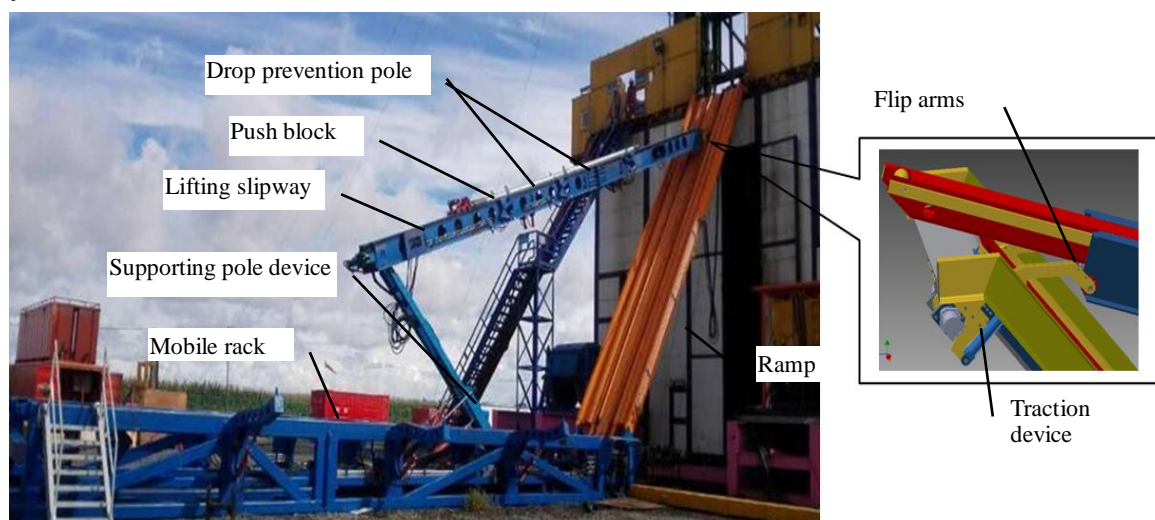

Fig.1 The structure of the rise-fall device

As shown in figure 1, the rise-fall device is mainly composed of traction device, lifting slipway, ramp, supporting pole device and mobile rack. The movement energy of lifting slipway is form the dragging movement of traction device in the ramp and the lifting movement of supporting pole device on the mobile rack. The functions of each part are as follows:

(1) Lifting slipway: It is mainly composed of drop prevention device, push block of drilling pipes and

slipway. This slipway is not only used to fix drilling pipes, but also provide a migration track for pipes.

(2) Traction device: It is driven by power motor and drags lifting slipway to move upward and downward along the ramp through the chain transmission mechanism. At the beginning of the upward movement, lifting slipway has a certain initial upward angle through the flip arms, which can greatly economize the dragging force from traction device.

(3) Ramp: Ramp connects the drilling platform with the mobile rack to provide movement track for lifting slipway.

(4) Supporting pole device: It is composed of supporting poles and hydraulic cylinders. As auxiliary power, its hydraulic cylinders can control space position of lifting slipway and economize the push force of push block.

(5) Mobile rack: It mainly includes the translational block assembly and roller components. It provides a supporting platform for the above equipment.

Design of Hydraulic System for the Rise-Fall Device

Design scheme of the rise-fall device is shown in figure 2, and it mainly has five oil-ways, and respectively controls the supporting pole device, traction device, push block, the flip arms and drop prevention device of drilling pipes. In this scheme, the key components adopted are shown as follows:

(1) Load sensitive hydraulic pump

When the size of workload is changed, this pump can automatically adjust the pressure and flow rate of the rise-fall device to satisfy the demand of workload through feedback loops, which can make the system in the stable state.
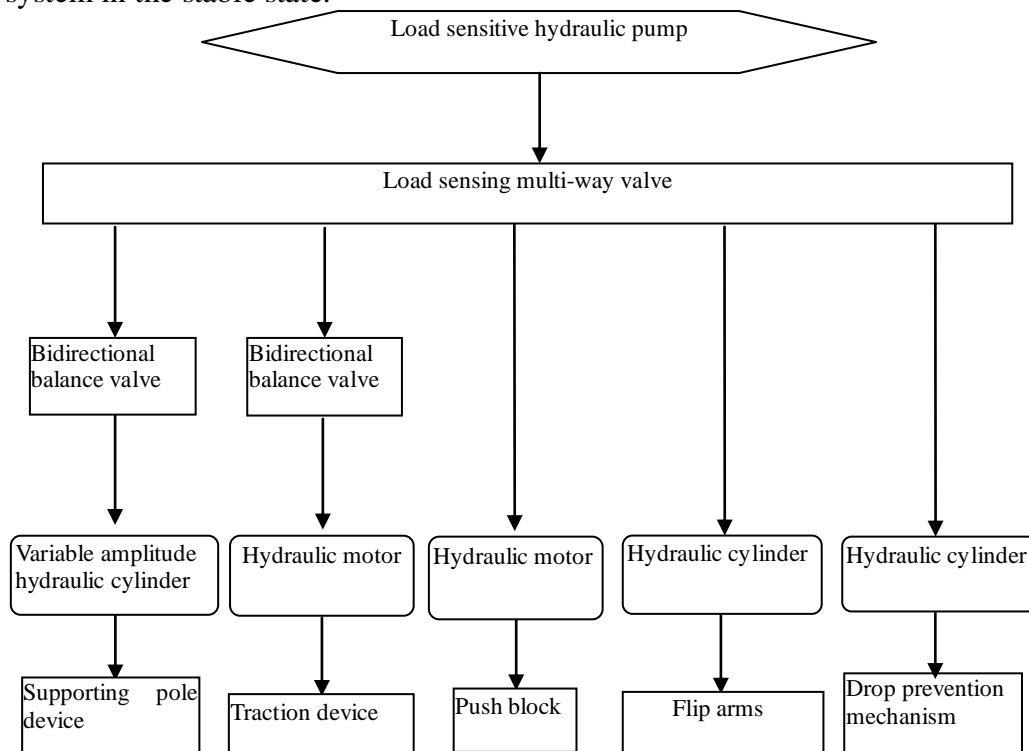
Fig.2 Scheme design of hydraulic system on the rise-fall device

There are two main characteristics about load sensitive hydraulic pump. One characteristic is its flow control characteristic. When workload changes, the supply flow of pump does not change, and the pump only adjusts its outlet flow to ensure the normal work of the system through some control signal. The other characteristic is that the pump can be cut off automatically when faced with high pressure. Pressure cut-off valve open when load exceeds a certain value, which is an important protection for the hydraulic system [6-9].

(2) Load sensitive multi-way valve

This kind of valve can enable multiple actuators (for instance, hydraulic cylinder or hydraulic

motor) to complete their respective action without mutual influence, and the speed of implementation device is only related with the displacement of the spool in main valve, but not the change of load pressure[10-12].

(3) Bidirectional balance valve

In the oil circuit of supporting rod device and traction device, the bidirectional balance valve can eliminate the high speed motion of hydraulic piston caused by the variation of load. That is to say, it can provide the delivery of drilling pipes with better stability.

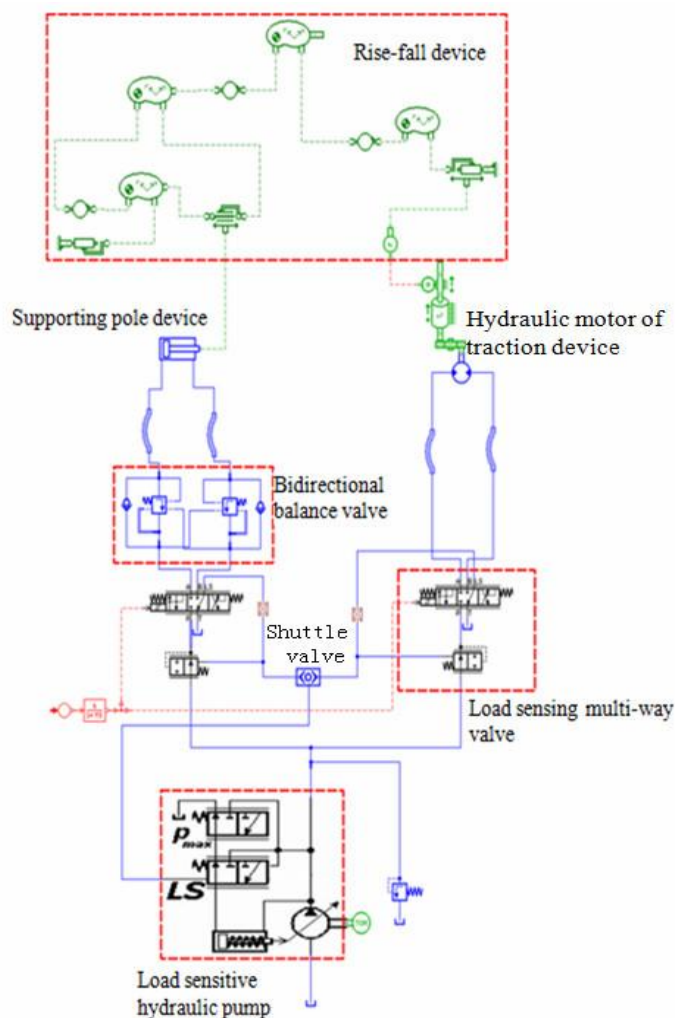**Hydraulic Simulation Analysis of the Rise-Fall Device**

Fig.3 Simulation model of hydraulic system in AMEsim

According to the hydraulic scheme in figure 2, establish hydraulic simulation model of the rise-fall device, as shown in figure 3, through the planar mechanism library in SMEsim software [13].

Test the flow response and pressure response of the hydraulic system model on the load sensitive hydraulic pump, the drag-off motor and hydraulic cylinder of supporting pole. And the results are as shown in figure 4 and figure 5.

(1) The flow of hydraulic pump in the system is always consistent with the size of the workload through the adjustment of the load feedback loop.

(2) During the operation of the rise-fall device, the difference between the outlet pressure of pump and the maximum value of load pressure is basically kept as a fixed value, which is about 26 bars. In 26.2s, when the rise-fall device runs to the end of stroke, the load sensing pump becomes in the cut-off state owing to high pressure. At that time, outlet flow of the load sensing pump reduces quickly to zero, and its outlet pressure is quickly rose to the initial 293bar, the set

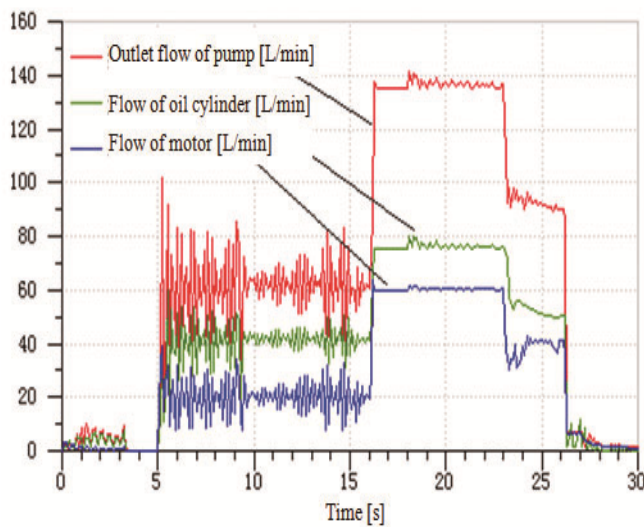value of this pump, which plays a protective role in the hydraulic system.

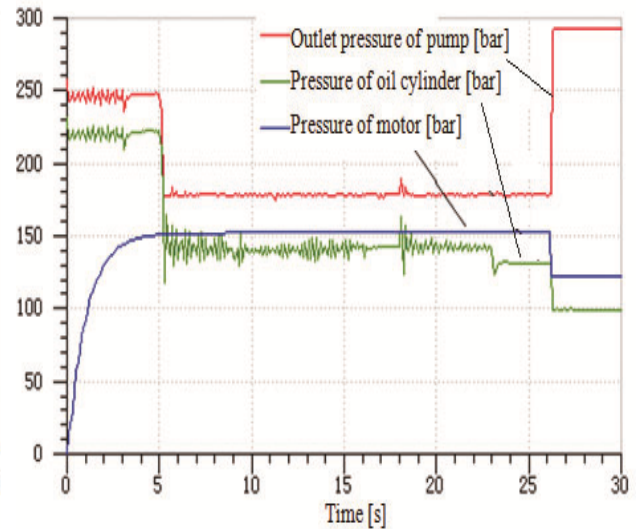**Fig.4** Flow response curve of the system

Fig.5 Pressure response curve of the system

Summary: The scheme of hydraulic system meets the requirements of the rise-fall device, and its corresponding functions can be played very well.

Test Analysis of the Rise-Fall Device

(1) Experimental objective: Test the flow response and pressure response characteristics of the hydraulic system.
(2) Experimental equipment: Rise-fall device, Electric control box, Hydraulic station, Test platform of drilling tool, pressure sensors, flow sensors, Φ127 Aluminum alloy drill pipe, Low temperature anti-wear hydraulic oil (L-HV32).
(3) Result analysis: Based on the flow and pressure data from the experimental result, flow response curves and pressure response curves shown in Figure 6 and Figure 7 are plotted.

In 0~26 seconds, the flow and pressure of the load sensing pump are consistent with the changes in the size of the load during the operation of the rise-fall device. In 26 second, the rise-fall device moves to the end of the stroke, and the load sensing pump becomes in a high pressure-cut off state. At this point, the pressure cut-off valve opens, flow rate of the system reduces to zero, while its force is up to 293 bars.
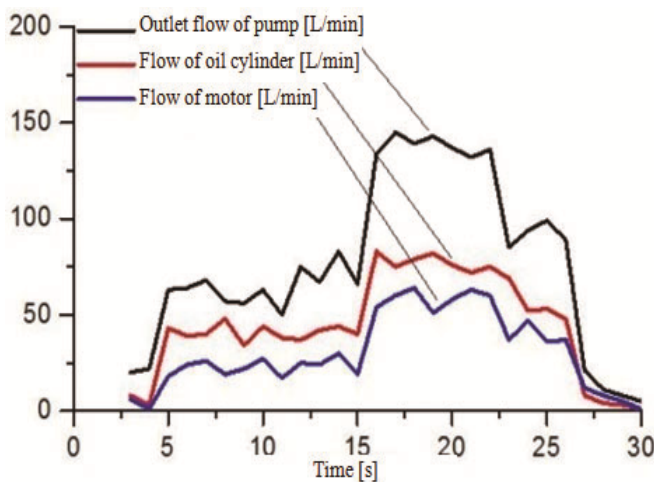

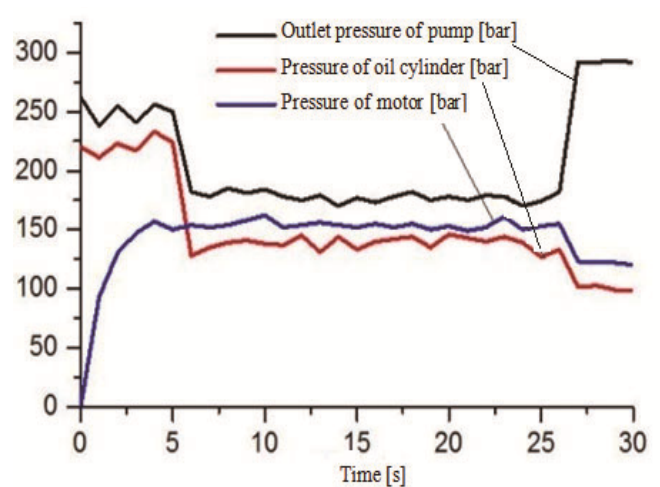
Fig.6 Flow response curves of the system

Fig.7 Pressure response curves of the system

Test Results of Hydraulic System

(1) During the operation of the rise-fall device, changes in pressure and flow are relatively stable, which reduce impact load and vibration of lifting slide. The results verify the feasibility of the design on the hydraulic system.

(2) Through the load feedback loop, the system can not only automatically adjust the flow and pressure to meet the load change, but also save energy to the maximum extent. When hydraulic system overloads, the pressure cut-off valve can also play a protective role in the hydraulic system.

(3) The experimental curves and simulation curves have the same variation law, so the simulation curve can reflect the actual change of hydraulic system within the error allowable range. These results can be used as a theoretical basis for the following design of the hydraulic system.

References

[1] ZHAO Shulan, LI Wenbiao, NIE Yongjin, SHI Nannan. The present situation and development trend of the power catwalk Technology at home and abroad [J]. Oil Field Equipment, 2010 39(2):13-15.

[2] KOU Hongtao, CUI Jianchun, LIU Haiwei, SONG Rui. The design and application of the hydraulic power catwalk for the conveyance of drill pipe [J]. Petroleum Machinery, 2008, 36(9):29-35.

[3] TAN Zhisong, YU Ping, ZHANG Chunpeng, LI Yanjiao. Kinematic analysis of lifting system in full hydraulic automatic catwalk [J]. Oil Field Equipment, 2015, 44(7): 24-27.

[4] ZHANG Peng. Research on the migration system of drill pipe in full hydraulic automatic catwalk [D]. Jilin: jilin university, 2014.

[5] GAO Jianqiang. Study on the rise system of full hydraulic automatic catwalk [D]. Jilin: jilin university, 2014.

[6] ZHU Jianxin, DAI Peng, et c. Analysis and optimization to the response characteristics of the load sensing pump [J]. Mechanical science and technology, 2015, 34(6):867-871.

[7] WANG Yan, HU Junke, YANG Bo. Dynamic characteristic analysis and simulation study of load sensing pump [J]. Modern Manufacturing Engineering, 2008, (12):84-95.

[8] REN Yan. Application of load sensing pump and proportional multi way valve in large machine [D]. Fluid Power Transmission and Control, 2008, 28: 30-31.

[9] MA Chong, XW Kong. Stability simulation and parameter optimization of load sensing pump [J]. Mechanical and Electrical Engineering Magazine, 2011, 28(5):548-552.

[10]ZHOU Xiong, ZHU Jianxin, LI Liang. Application of load sensitive control in hydraulic drilling machine [J]. Machine tools and Hydraulics, 2007, 35(8):129-130.

[11]SUN Wei. Design and Simulation of load sensing multi way valve [D]. Xiangtan: Xiangtan University, 2013.

[12]Coord3 S.p.A. Measuring software for coordinate measuring machines Versions 3.7[M]. 2001, 4.

[13]FU Yongling. Imagine. Lab AMESim LMS system modeling and simulation examples tutorial [M]. Beijing: Beijing University of Aeronautics and Astronautics Press, 2011.