JJMIE

Volume 14, Number 1, March. 2020
ISSN 1995-6665
Pages 37 - 41

Jordan Journal of Mechanical and Industrial Engineering

The Application of Closed Hydraulic System of Hoisting Mechanism in Auto Crane

Duwei Nie*, Changxing Fu

Department of Mechanics Engineering, Huaihua Polytechnic College, Huaihua 418000, China

Received OCT 16 2019   *Accepted JAN 5 2020*

Abstract

At present, the hoisting mechanism of existing large-tonnage auto crane has mostly adopted open loop hydraulic system; for security reasons, the load loop tends to input larger load, causing unnecessary energy loss of engine. In order to solve this problem, the closed hydraulic system for the load loop carries on constant power control for load input power to ensure the constant control of optimal load rate of engine, which achieves the safety and energy saving of the auto crane. According to the principle that the power of hydraulic system is equal to the product of pressure and flow in the system, as long as carrying on constant control for the pressure and flow in hydraulic system, the closed loop control of hydraulic system can be realized.

Keywords: Auto crane; Load input; Constant power control.

1. The working principle of Closed hydraulic system for lifting mechanism of autocrane

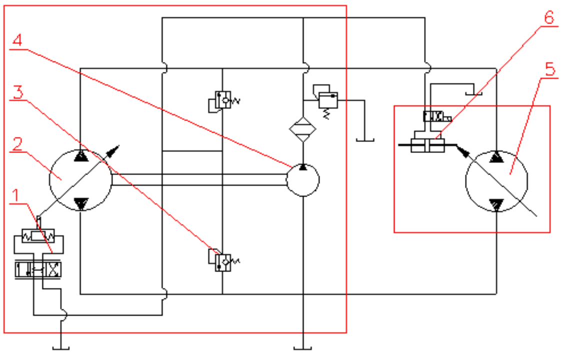
Because of the hydraulic transmission with large output force, small volume, light weight, simple structure, labor-saving transmission and operation, it iseasy to realize stepless transmission and automatic control etc., hydraulic lifting mechanism widely applied. Especially in modern engineering crane, automobile crane and crawler crane widely use the hydraulic transmission mode [1].

Auto crane hoisting mechanism has two main systems, namely the valve-controlled motor open-loop control system and the pump-controlled motor closed-loop control system.

The valve-controlled motor open-loop control system belongs to the restrictive-flow regulating system. Its biggest characteristic is simple system device, low costs and easy design as well as a large speed range, which is very beneficial to the micro-motion of auto crane [2]. However, due to the existing damper loss and low working efficiency, the system's calorific value is higher.

The pump-controlled motor closed-loop control system is a kind of volumetric speed control system. Because this kind of circuit does not have the throttling and overflow energy loss, the system is not easy to heat and its efficiency is high. It is widely used in high power hydraulic drive system, but due to the required high manufacture precision and the complicated structure, the cost of the hydraulic device is higher.

The schematic diagram of closed Hydraulic System for Hoisting mechanism of Auto crane is shown in Figure 1. The oil inlet and outlet of the variable electro-hydraulic proportion pump 2 are connected with the oil inlet and outlet of variable motor 5 respectively to form a closed circuit, so that the ascending or descending of main windlass can be achieved. To supplement the internal leakage of the motor due to the volumetric efficiency, a charging pump (usually a dosing pump) is added to the system to charge the system. This charge pump also provides the system with a source of controlling oil. The variable electro-hydraulic proportion pump2 can change its output through its variable servo. The electro-hydraulic proportion motor can also change its displacement through its variable servo so that the system can achieve a wide range of speed regulation.



1. variable servo; 2. variable electro-hydraulic proportion pump; 3. charging relief valve;4. charging pump; 5. variable electro-hydraulic proportion motor; 6. variable servo

Figure 1. Schematic diagram of closed Hydraulic System for Hoisting mechanism of Auto crane

* Corresponding author e-mail: Dwnie2000@126.com.

When we operate a crane to make the weight drop, the weight's direction of gravity is the same as the movement direction, the weight drives the motor to rotate. At this moment, the motor and the pump change in function, the winding motor is no longer as executing components to absorb the power of the engine, but as a dynamic element to provide power to the engine, it will cause the load rate of engine lower than zero which leads to the rise of rotational speed, when it becomes serious that the engine will show "speed" phenomenon. In order to prevent the "speed" phenomenon of the engine, it is usually to load power and input circuit in the closed hydraulic system of automobile hoisting crane, to consume the power produced by the load drop of the lifting engine, in order to ensure that the engine load rate is greater than zero. The power consumed by the load loop is equal to the product of the pressure P and the flow Q [3].

$$P_t = PQ$$

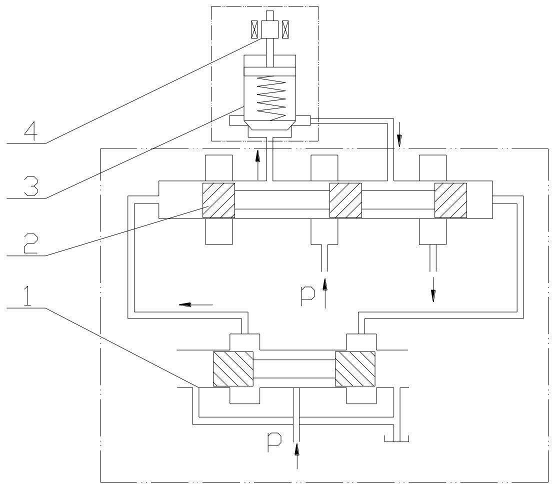
The constant control of the input load power in the field of the existing large tonnage truck crane is mainly open loop control. Due to the shortcomings of low control precision, weak anti-interference ability and so on, it cannot meet the realistic needs. In practice, it will often input greater load for the safety of the crane itself and the crane operator, causing high load rate of engine, thus resulting in unnecessary energy loss of the engine.

In order to solve this problem, we adopt the closed hydraulic system. When in condition of the main hoist down, due to the influence of the factors of wind load and inertia force and so on, the load rate of the engine is dynamic change. By taking closed control of the system pressure P and flow rate Q, it is to realize the optimal constant control of engine load rate, which can not only ensure the safety of the crane in the condition but also ensure the engine output power in the most energy state, to realize the constant control of the input load power.

2. The establishment of physical model of Closed Hydraulic System for Hoisting mechanismof Auto crane

Closed hydraulic system for hoisting mechanism of auto crane load input circuit mainly includes pilot-scale proportional servo flow valve and proportional relief valve. As shown in Figure 2 of physical model schematic diagram, pressure oil controlling oil passage enters into proportional servo console port through action of proportional electromagnet of pilot operation 1. It pushes valve core 2 of proportional flow servo valve to have respondent action. Pilot valve and main valve are slide valve structures. If we ignore the effect of flow force, force of fiction, valve core weight and spring force of pilot valve, then the control force of pilot reducing valve is in direct proportion to electromagnetic force. If we ignore the effect of flow force, valve core weight and force of fiction of pilot valve, control power is in direct proportional to main valve core displacement. By changing current of input proportional electromagnet, we can control main valve displacement and aperture [4]. Hydraulic oil from main valve of proportional servo valve enters proportional relief valve 3. Proportional relief valve sets its pressure through current or voltage value of proportional electromagnet 4. Continuous overflow of proportional relief valve consumes power created by gravitational potential energy of carrying heavy things in over loads, to prevent galloping of the engine.

By comparing the mathematical modeling of the electromagnet, the mathematical modeling of the proportional relief valve and the mathematical modeling of the proportional servo flow valve, we can obtain the electro-hydraulic coupling model (not to be deduced here). Then we can build a simulation model of hydraulic circuit of Hoisting mechanism of Auto crane by using AMESim software.

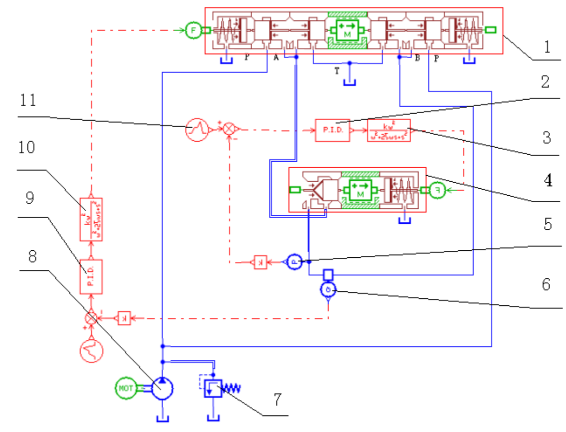


1 proportional servo valve pilot 2 main valve of proportional servo valve 3 proportional relief valve 4 proportional electromagnet.

Figure 2. Physical model schematic diagram

3. The Establishment of closed Hydraulic System Simulation Model for Hoisting mechanism of Auto crane

AMESim (Advanced Modeling and Simulation Environment for Systems Engineering) is the world famous engineering system and advanced modeling and simulation platform [5]. It provides a whole, full and systematic engineering design and simulation platform, which makes it possible for users to establish a complex and multidisciplinary electro-mechanical and hydraulic integrated system model on a single platform, and conduct the simulation calculation and deeper analysis on this basis. AMESim is growing rapidly. Its main product modules include four operation platforms[6], one 3D animation front-back Processing Toolbox, 28 application model bases(A total of 3500 models), 5 Interface Tools, 1 optimal toolbox and 10 real-time simulation code generation function[7].



1. Proportional flow valve 2. PID adjustable controller 3, Transfer function 4, Overflow valve 5 ,Pressure sensor 6 ,Flow sensor 7, Safety valve 8 ,Hydraulic pump 9 ,PID adjustable controller 10, Transfer function 11. Step-function signal

Figure 3. Closed-loop Control Simulation Model

By using AMESim signal control library, hydraumatic library (including pipe model) and hydraulic component design library, we conduct modeling on investigative control system and hydraulic component, as shown in Figure 3. Meanwhile, it depends on its super strong computing power to carry out dynamic characteristics analysis on the system [8].

Pressure (flow) sensor transfers detective real-time pressure (flow) data to summator through proportional gain. Compared with step-input signal, with regard to the different values between them as input signal of PID adjustable controller. PID adjustable controller adjusts finished signal and acts on valve element of proportional overflow through transfer function and spring force sensor, so as to reach predicted pressure and flow value ultimately.

4. Dynamic characteristics of Closed Hydraulic System for Hoisting mechanism of Auto crane

For whatever reasons (external disturbance or system internal variation), as long as controlled variable deviates from specified value, closed-loop control system will generate corresponding control actions to eliminate deviations, have a thick skin on component characteristic variation and can improve visible response characteristics of system. Closed-loop control has stronger capacity of resisting disturbance, which can avoid from load rate's fluctuation of hoisting mechanism in suspended loading process. Even if it is impacted by dynamic factors of dynamic wind load, it also can eliminate interference rapidly.

Simulation parameters for closed-loop control simulation model of Hoisting mechanism of Auto crane are designed as shown in Table 1.

Table 1. simulation parameters

parameters names	parameters
motor speed	1000 r
pump emissions	45 ml/r
simulation time	10 s
simulation step	0.01s

The pressure dynamic curve for inlet of relief valve by simulation is shown in Figure 4.

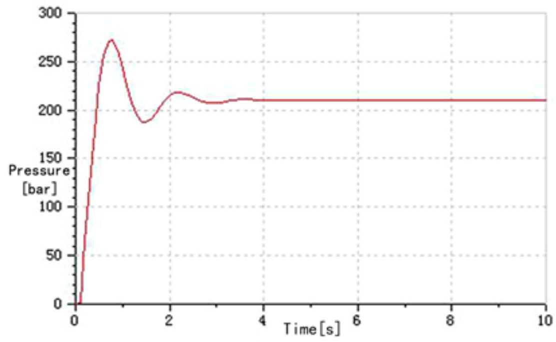


Figure 4. Curve of Closed-loop Control Pressure's Dynamic Characteristics

Dynamic response time of closed-loop control pressure can be controlled within 2 second with overshoot kept within 23% [9-11].

Dynamic characteristics for outlet flow of electro-hydraulic proportion multi-way valve are shown in Figure 5.

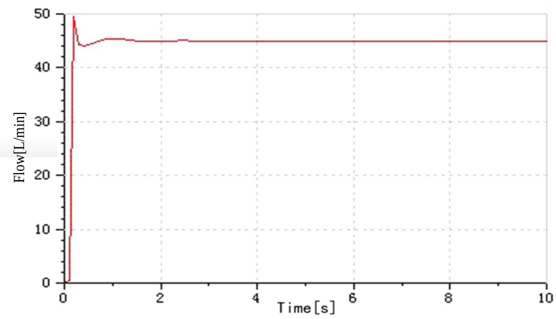


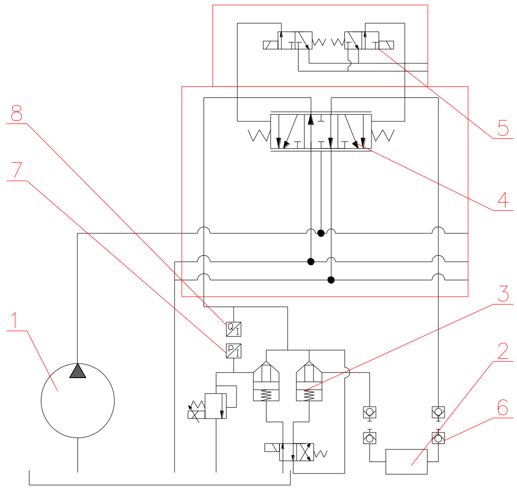
Figure 5. Closed-loop Control Flow's Dynamic Characteristics Curve

Dynamic response time of closed-loop control flow can be kept within 0.5 second with overshoot kept within 10%.

5. Experimental verification of Closed Hydraulic System for Hoisting mechanism of Auto crane

Taking the all terrain crane with the rated load of 400 tons that an enterprise produced as an example, a set of closed system is installed on the hoisting mechanism of the crane.

 © 2020 Jordan Journal of Mechanical and Industrial Engineering. All rights reserved - Volume 14, Number 1 (ISSN 1995-6665)



1. Hydraulic pump; 2. Idle executive component; 3. Cartridge reversing valve; 4. Electro-hydraulic proportional multi-way valve; 5. Pilot-operated reducing valve; 6. Quick-change connector; 7. Pressure transducer; 8. Flow transducer

Figure 6. Load input closed-loop control system and test system schematic diagram

As shown in Figure 6, Hydraulic pump 1 provides the hydraulic oil source to the system, Pilot-operated reducing valve 5 is placed in the right position to control the electro-hydraulic proportional multi-way valve4. After passing the electro-hydraulic proportional multi-way valve, the hydraulic oil goes through the cartridge reversing valve into the relief valve. When the set relief valve pressure is reached, the hydraulic oil will overflow out through the relief valve and consume the produced engine power when the crane falls down. Therefore, it realizes the consumption of energy as heat. When the crane is affected by the factors of wind load and inertial force and leads to the changes in temperature and pressure, the pressure transducer 7 and the flow transducer 8 detect the real-time pressure and flow of the load input loop. Compared with the set pressure and flow value, it can quickly reach the set value through the closed-loop feedback.

Hydraulic system flow curves for open-loop and closed-loop control are collected as shown in Figure 7 and in Figure 8 when the main windlass is lifting 8 tons of weight.

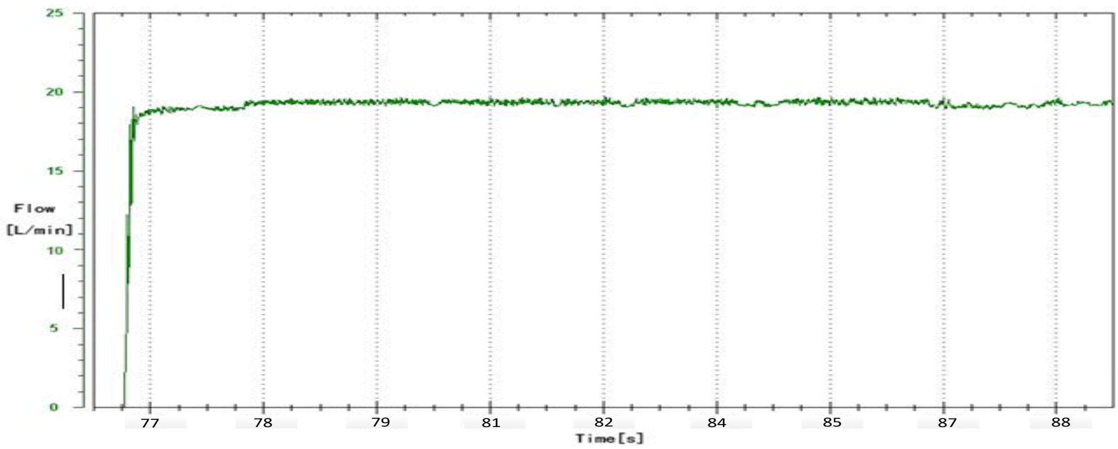


Figure 7. Hydraulic system flow curves for open-loop when the main windlass is lifting 8 tons of weight

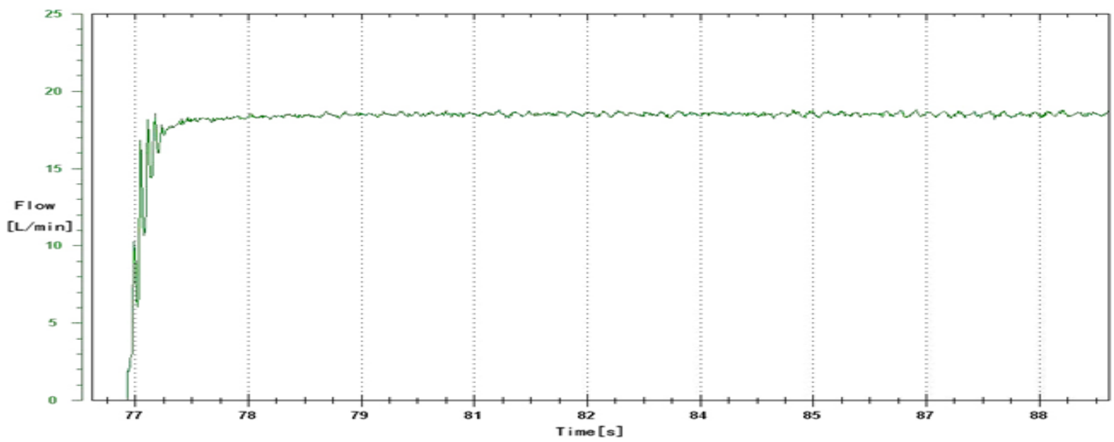


Figure 8. Hydraulic system flow curves for closed-loop when the main windlass is lifting 8 tons of weight

It can be seen from the figure that the open-loop control system has serious oscillations in the suspension process and is greatly affected by the wind load or other factors. When the flow rate is set to 18L, the static error exceeds 1.5 L, accounting for about 8%; The closed-loop control response time does not exceed 1s, the static difference can be controlled at 0.3L, accounting for about 1.5%, the oscillation is significantly reduced, indicating that its anti-interference ability is significantly better than the open-loop control system.

Pressure curve curves for hydraulic system of open-loop and closed-loop control are collected as shown in Figure 9 and in Figure 10.

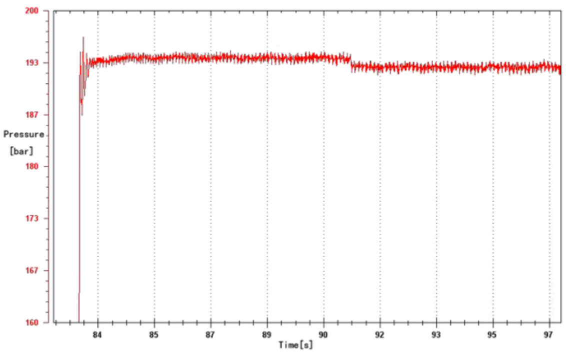


Figure 9. Pressure curve for open-loop control system when the main windlass is lifting 8 tons of weight.

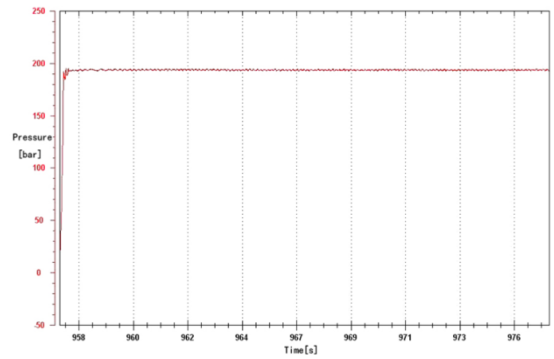


Figure 10. Pressure curve for closed-loop control system when the main windlass is lifting 8 tons of weight.

As can be seen from the figure, compared with the closed-loop control, the open-loop control system has no significant differences in the speed and oscillation of the response time without any other dynamic factors. However, when wind loads or other dynamic loads occur at 91 seconds in Figure 10, the open-loop control system shows obvious oscillations, static increase and can't be eliminated for a long time. In the closed-loop control system, the anti-interference ability is obviously better than that of open-loop control system.

We can draw a conclusion of analysis on pressure and flow dynamic characteristics that closed-loop control system has advantage in anti-jamming capability and eliminating offset capacity compared with open-loop control system. Therefore, with wind load capacity and other strong dynamic load capacity of closed-loop control system, can be applied to loan input circuit of crane closed winch system in over loan situation. When loan rates of engine is reduced, the security of crane is guaranteed.

6. Conclusions

When the crane is influenced by wind loads, inertia force and other factors, through the closed-loop control of system pressure P and flow Q to the loading loop, closed hydraulic lifting mechanism changes from being disturbed by external dynamic load to the state with stable time within 1 second and not produce the "speed phenomenon" to the engine so as to ensure not only the safety of crane in this situation, but also the output power when the crane is in the most energy-saving state, realizing the constant control over input load power.

Acknowledgment

This research is supported by Hunan Provincial Department of Education Funding Project (17C1291).

References

[1] Xiaoming Wang. Zhiqiang Lu. Research of Current Status and Development Trend of Large Cranes both at Home and from Abroad, Development and Innovation of Electromechanical Products. 2009, 12(3):6-8.

[2] Aiwu Zhang. Design of Hydraulic System of Medium-and-Large Truck Cranes. 2007, 26(12):92-95.

[3] Tai Zhang. Dynamic Study of Mechanism of Automobile Crane. Beijing: Mechanical Engineering, 1998, 34(6):8-10.

[4] Wang Yilun. Hydraulic transmission, Harbin: Harbin Engineering University Press, April 21, 2005.

[5] Yongling Fu, Haitao Qi. LMS Imagine. Lab AMESim system modeling and simulation example tutorial, Beijing: BEIHANG University Press, July 2011

[6] Wilfrid Marquis-Favre, Eric Bideaux, Serge Scavarda. A planar mechanical library in the AMESim simulation software. Part l: Formulation of dynamics equations. Simulation Modeling Practice and Theory, 2005, 3-17.

[7] Jiasheng Qin, Shanlan You. AMESim software characteristics and application, Construction Machinery, 2004, 47 (12).

[8] Changzheng Huang, Jianping Tai. Current Status and Development Trend of Hydraulic System Modeling and Simulation Technology. Journal of Shaoguan University, 2009, 3:43-47.

[9] Baligidad Sagarm, Krishnamurthy N, N Narendra. Development of an economic tensile and torsion testing machine for wires. Open Journal of Mechanical Engineering, 2016, 1(1):15-18.

[10] Leonhard E. Benold, Simulation of Nonsteady Construction Processes, ASCE, 2009, 163-178.

[11] Das Indrajit, Halder Arnab, Roy Sanjoy. Secure medical image sharing and storing (image encryption and hiding) in cloud environment. Advances in Industrial Engineering and Management, 2016, 5(2):208-213.