Two-cylinder Synchronization Control and Simulation of ROV Launch and Recovery System “A Shape” Frame

Zhang Wei 1, a, Sun Bin 2, b, Li Bin 3, c, Tang Shi 4, d

1, 2, 3, 4 Shenyang Institute of Automation Chinese Academy of Sciences, Shenyang, China

a siazhangwei@163.com, b Sunb@sia.cn, c Lib@sia.cn, d sha_yangzi@163.com

Keywords: Counterbalance Valve, Proportional Valve, Synchronization Control, AMESim

Abstract. This paper focuses on “A shape” frame’s two-cylinder synchronization control of Remotely Operated Vehicle (ROV) launch and recovery system. First, two-cylinder synchronization control scheme with counterbalance valve and proportional valve is proposed. Second, counterbalance valve model is established, and its supercomponent is generated. Finally, simulation of synchronization control system is performed. After adjusting PID controller parameters, displacements error of two cylinders is controlled in the allowed range.

Introduction

Remotely Operated Vehicle (ROV)’s main mission and task is the auxiliary equipment of cooperating Deep Submarine Rescue Vehicle (DSRV) to rescue wrecking or sinking submarine. It can independently take the tasks of supporting sea trials of new developed equipment, searching, observing, salvaging valuable underwater objects and monitoring, inspecting underwater environment of reserved sea area.

ROV launch and recovery system as shown in Fig.1 installed on the DSRV is a special tool to launch and recover ROV. Working “A shape” frame will undertake varying load when swing outside or inside and static load when ROV is at work. Therefore, two-cylinder synchronization control of “A shape” frame will affect not only the frame stiffness and service life, but also ROV pose position and orientation.

Synchronization Control Scheme

Flow distributing and collecting valves and synchronous motors are usually used to control two cylinders’ synchronous motion. However, there is larger displacement error as the loads become larger and valve’s machining error and delayed response exist. In this paper, synchronization control scheme with counterbalance valves and proportional valves is proposed to get better synchronization control performance. The simplified hydraulic scheme only with key components that affect synchronization simulation much is drawn in Fig. 2. Cylinder 1.2 is the active cylinder whose displacement and velocity is controlled by proportional valve 3.2. And passive cylinder 1.1 is controlled by proportional valve 3.1 according to the displacement error signal of the two cylinders.

Counterbalance Valve Model

A counterbalance valve is designed to restrict fluid flow from an actuator to prevent cavitation at the inlet port of the actuator which would occur if the load caused the actuator to move faster than the supply coming from the pump [1].

We used AMESim software to establish counterbalance valve and the followed whole hydraulic scheme simulation. AMESim is a multidisciplinary modeling, simulation and analysis software that allows to link between different physics domains as hydraulic, pneumatic, mechanic, electrical, thermal, and Electro-mechanical. In this paper, the simulation program is developed using AMESim 4.3.0 version [2].
Establish two-counterbalance valves simulation model as shown in Fig. 3 according to the single counterbalance valve model of screw-in cartridge style, which is described in article [3]. And, establish the counterbalance valve supercomponent as shown in Fig. 4 to reduce its icon area [4].

**Synchronization control simulation**

Establish hydraulic scheme simulation model of two-cylinder synchronization control in AMESim as shown in Fig. 5. According to the ROV launch and recovery system at service now, parameters of simulation model was set as follows: oil density 890kg/m³, oil dynamic viscosity 40mm²/s, oil volume modulus 1000Mpa, cylinder piston diameter 250mm, cylinder piston rod diameter 160mm, cylinder piston stroke 2500mm, pump output 140mL/r, motor speed 1450r/min, relief valve opening pressure 21MPa.

Set the control signal of proportional valve on the right, which can also be manual proportional valve, as shown in Fig. 6 that the cylinder piston can reach its extreme position, 2500mm. The displacement curves of cylinder pistons is shown in Fig. 7, from which we can find that the pistons reach their extreme position, stretch out approximately from 0s to 10s, and retract approximately from 30s to 40s. In the above process, the loads on the cylinder pistons vary from the most-positive load to the most-passive load when stretching out, and from the most-passive load to the most-positive load when retracting. According to the two-cylinder displacement curve, set the load acted on the two cylinder pistons as shown in Fig.8.

We need to ensure the active cylinder move steadily. Although we adjusted the PID controller parameters, setting Kp, Ki, Kd to be 30, 1, 5, getting better piston velocity performance, there is still vibration at the beginning, which is caused by the counterbalance valve. The velocity curve of cylinder piston after adjusting is shown in Fig. 9. Therefore, we need to control the active cylinder piston to stretch out more slowly at the beginning.
Finally, we get displacement error curve of the two-cylinder piston as shown in Fig. 10. After adjusting PID controller parameters of the passive cylinder, the error is reduced from 3.2mm to 1.5mm, as shown in Fig 11.
The material of beam is 45# steel. Its stress intensity is $600\text{N/mm}^2$, and elastic modulus is 210Gpa. Therefore, the allowable strain of the beam is

$$\varepsilon = \frac{\sigma}{E} = \frac{600 \times 10^6}{210 \times 10^9} = 2.86 \times 10^{-3} \text{mm/mm}$$

From Fig. 11, we can find that two-cylinder error is biggest at the beginning, which is no bigger than 1.5mm. “A shape” frame beam length is 4m, so the beam biggest strain is

$$\varepsilon = \frac{\Delta L}{L} = \frac{1.5}{4000} = 3.75 \times 10^{-4} \text{mm/mm} < [\varepsilon]$$

We can see the beam actual stain is far less than the allowable stain, so it can satisfy the usage requirements well.

**Summary**

This paper proposes two-cylinder synchronization control scheme with counterbalance valve and proportional valve. Establish counterbalance valve model and its supercomponent. Finally, from the simulation result in AMESim, after adjusting PID controller parameters, the error of two-cylinder displacements is controlled in the allowed range and can satisfy the usage requirements well.

**References**

[1] Muhammad M. Rahman, Jose L. F. Porteiro, Steven T. Weber. Numerical Simulation and Animation of Oscillating Turbulent Flow In A Counterbalance Valve, Energy Conversion Engineering Conference, (1997), P. 1525-1530.

[2] Sung Hee Park, Khairul Alam, Young Man Jeong, Chang Don Lee, Soon Yong Yang. Modeling and Simulation of Hydraulic System for a Wheel Loader using AMESim, ICROS-SICE International Joint Conference, (2009), P. 2991-2996.

[3] Liang Hongxi: Numerical Analysis of the Dynamic Characteristics in Hydraulic Counterbalance Valve, Lanzhou University of Technology, Lanzhou, (2011), p.46.

[4] LMS IMAGE. Hydraulic Component Design. (2008), P.60-75.