Dynamic Simulation and Analysis on Elevating Process of Elevating Equilibrator

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Abstract. The elevating equilibrator is used to control the elevating angel of the director of a rocket launcher. Based on an elevating equilibrator, a method for co-simulation is introduced with dynamic simulation software ADAMS and hydraulic simulation software EASY5. A three-dimensional model of the elevating equilibrator is developed with Solidworks and is imported into ADAMS. Furthermore, the hydraulic system model is established by EASY5. The interaction of mechanical system and hydraulic system is analyzed. The analysis indicates that the modeling method for co-simulation is effective and practical.

1 Introduction

The elevating equilibrator is a relatively complex action mechanism and used to control the elevating angel of the director of a rocket launcher. As the mechanism is simulated, the mechanical system and hydraulic system should be analyzed together. In this paper, the virtual prototype of the elevating equilibrator is established with ADAMS and hydraulic system model is established with EASY5 respectively. Then co-simulation is achieved by dynamic data exchange between two models [1]. Because of a large load generated when elevating equilibrator working, the dynamic simulation and analysis on elevating process of elevating equilibrator is of great significance [2].

2 Mechanical and hydraulic system modeling

2.1 Elevating equilibrator modeling

The elevating equilibrator is constituted of hydraulic cylinders and energy accumulator. Significantly the hydraulic cylinder is composed of a fixed piston rod, a moving piston rod and sealing elements, and, the upward, downward and balance cavities are in the hydraulic cylinder. The accumulator includes a variable accumulator volume and an optional fluid tee-section that connects to adjacent components. The elevating equilibrator is shown in Fig. 1.

The elevating equilibrator model that is established and assembled in Solidworks software[3] is imported into ADAMS software and simplified on the basis of the dynamic relation. The dynamic simulation and analysis are in progress after the material properties defined and joints and load created. The virtual prototyping model is shown in Fig. 2.

2.2 Hydraulic system modeling

2.2.1 Hydraulic system circuit

Hydraulic oil flows into upward and downward cavity through the hydraulic system circuit, which controls the
elevating process, and the location of machine is fixed by
the hydraulic lock composed of two hydraulic control
check valve. The circuit is established in EASY5 software,
which includes the creating of hydraulic oil, pumps, sinks,
cylinders and various control valves. Hydraulic system
circuit is shown in Fig. 3.

Figure 3. Hydraulic system modeling

In the hydraulic system model, the elevating process
and the hydraulic lock are controlled by the 4-way valve
and two 3-way valves respectively. The system pressure
is limited for the relief valve, and energy is storage and
reused by the energy accumulator.

2.2.2 Parameter setting

It is of significance to configure parameters of oil
properties, power components, actuator components and
various controllers. #10 aircraft hydraulic oil
(SH0358-1995) is chosen to be used in the circuit, and
the fluid temperature(TC), ambient temperature and
pressure are defined on basis of the working condition.

Force formula of the cylinder is:

\[ F = P_1A_1 - P_2A_2 = P_1 \frac{\pi D^2}{4} - P_2 \frac{\pi (D^2 - d^2)}{4} \]

where F is the force of hydraulic cylinder, \( P_1P_2 \) stand for
oil pressure of extend and retract chamber, and \( A_1A_2 \) stand
for piston area of extend and retract chamber. The
parameters of the cylinders and other components are
designed, and the parameters are shown in Table 1.

Table 1. Parameters of Hydraulic Circuit

| Parameter       | Value |
|-----------------|-------|
| PC_RF(bar)      | 300   |
| PFO_RF(bar)     | 320   |
| TC_RF(s)        | 0.01  |
| PCK_VC(bar)     | 1     |
| APE_AP(cm²)     | 50    |
| APR_AP(cm²)     | 40    |

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3 Co-simulation of ADAMS and EASY5

New design variables are created in ADAMS software
including an input variable (force) and two output
variables (displacement, velocity) are shown in Table 2.

Table 2. State Variables Designed

| State Variable | Type  | Meaning                         |
|----------------|-------|---------------------------------|
| Force          | Input | Force to Piston Rod             |
| Displacement   | Output| Displacement of Piston rod      |
| velocity       | Output| Velocity of Piston rod          |

And these variables are connected with ADAMS
Mechanism Component (AD) in EASY5 software through
the ADAMS/Control and EASY5/Extension interface. In
Chosen Execution Mode, the Function Evaluation (no
feed-through) is selected[5].

The ADAMS/View is started through the EASY5
Command Shell, and the control file of model (.cmd) and
hydraulic control system file (.dll) are imported into virtual
prototyping model. When interactive simulation was
using, simulation process always failed because integral
can not converge. Therefore the scripted simulation
method is determined which controls integral steps by
expression command[6]. Simulation integral step is 0.0005
before 13s and 0.005 before 15s, which is determined by
repeated simulation test.

4 Results and analysis

4.1 Motion process analysis

Starting from 1s, the piston rod rises at a constant speed
and drops from 8s at the same speed. When the 4-way
valve is working, a shock will be engendered between
hydraulic oil and both sides of piston rod. Because of that,
at 1s and 8s, the velocity of piston rod will change rapidly
and stabilize in a very short period of time. At 13s, the hydraulic circuit is locked by the hydraulic lock, and the motion of piston rod is stopped. The simulation results of the velocity and displacement are shown in Fig.4 and Fig.5.

![Figure 4. Velocity of Piston Rod](image)

![Figure 5. Displacement of Piston Rod](image)

### 4.2 Force analysis of piston rod

In this simulation, the hydraulic oil pressure in the upward cavity and downward cavity are shown in Fig.6.

![Figure 6. Changes of Pressure in Cylinder](image)

### 4.3 Flow analysis of relief valve and directional valve

Flow is a very important parameter for the hydraulic control system. At the level of balance machine complicated system, the flow parameters are difficult to be measured. Through the above analysis, the preliminary confirmation of co-simulation model established is consistent with the actual working conditions. So the flow analysis for the complex components can be finished by co-simulation.

The flow parameters of the relief valve and the 4-way valve are shown in Fig. 8, 9, 10. From the figure, the flow can be analysed, when the mechanism is stopped, the relief valve is fully open, the flow is to a maximum value of 49.09 cm³/s. At the rising stage, the flow from port 1 of 4-way valve is positive, and the value of port 2 is negative. At the downward stage, the flow of port1 and port2 is just the opposite.
For it is difficult to place the sensors in the actual machine, the parameters of the flow is not easy achieved. It is feasible and effective to calculate the flow parameters through the simulation analysis. It provides the basis and reference for the further research of hydraulic system and related properties.

5 Conclusion

The virtual prototyping model of elevating equilibrator is established by Solidworks and imported into ADAMS. The hydraulic control system model is built in EASY5, and co-simulation is executed through dynamics data exchange. The models are in agreement with actual working situation and can provide reference for related research in the future. The direction of oil flow changing, the shock force to piston rod is of significant influence on the working performance and service life and should be considered on the design and calibration.

Using this model, the flow parameters of the relief valve and the valve are solved. It is difficult to add sensors in a complex mechanism when the actual mechanical is working. So the virtual prototyping simulation technology can be used to measure different parameters. This provides a new solution to solve practical engineering problems and can provide reference and basis for fault diagnosis and so on.

References

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