Sensitivity Analysis of System Deviation of Swing Drive Test Device in Motion Conditions

WANG Xiaoyan*, GONG Zili, YU Shengzhi
Wuhan Second Ship Design and Research Institute, Wuhan, 430064, China
*Corresponding author’s e-mail: wangxiaoyan0704@foxmail.com

Abstract. The swing test device is a complex electro-mechanical-hydraulic system. The test body floats on the water and is swayed by the hydraulic traction devices on both sides of the pool. The precise control of the test body’s motion state by the hydraulic control system is affected by various external factors. Among them, the manufacturing equipment dimensions, test body weight and shape tolerances, and installation error of the equipment have a particularly serious influence on the control. Through the sensitivity analysis of external interference factors, this paper provides useful reference for device manufacturing, installation, operation, safety strategy, human factors control, etc.

1. Introduction
The sway drive system is a drive device that causes large swings to simulate serious sea conditions under laboratory conditions. The rolling in the floating state of the test cabin is affected by the viscous action of water, the lapping action of water waves, the mixed and alternating action of the rope driving force, the unbalance action of buoyancy and gravity, as well as the size, weight, appearance and installation accuracy of the cabin, which causes great interference to the control system of the swing drive system. So the sensitivity analysis of external influence factors is particularly important to sort out the interference sources and analyze the factors impact weight.

2. Device introduction
This test system is based on the principle of resonance. Several groups of hydraulic systems are used to apply excitation torque to the cabin section. The driving frequency is equal to the natural frequency of the cabin section, which causes the cabin section to resonate and the amplitude to gradually increase. Due to the existence of system damping, when the amount of energy consumed by the damping is equal to the input energy of the hydraulic system, the energy balance is balanced, and the steady-state response of the cabin section is equal amplitude harmonic roll [1][2].

The stand consists of three parts: mechanical system, hydraulic or electric servo drive system and control system, as shown in Figure 1. As a power source, the hydraulic equipment can apply rolling moment to the cabin section through a wire rope, and provide a simulated movement environment of the cabin section rolling.
3. Analysis of influence of construction deviation on driving capacity

3.1 Deviation range

During the construction process of the test body, for some objective reasons, there is a certain manufacturing deviation. The main parameters affected are mass, radius, and lateral stability. According to the requirements of CB/T4000 and reference to the requirements of the ship, the test body parameter variation range is set, as shown in Table 1. Small changes in the parameters of the test body will affect the sway period, sway acceleration, and recovery torque, etc., and thus affect the driving ability of the sway drive system.

| Parameter name                  | Variation range |
|---------------------------------|-----------------|
| Quality: m                      | ±1‰            |
| Radius: R                       | ±1%            |
| Transverse heart height: h      | ±10%           |

3.2 Impact of deviations on driving capacity

3.2.1 Mass deviation

In the case of other parameters taking standard values, when the test body mass m changes between -1 % to +1 %, the main parameters of the system change as shown in Figures 2 to 5.
It can be seen from Figure 2 to Figure 5 that the larger the mass of the test body, the greater the rotational inertia. However, the change in mass does not affect the maximum swing angular velocity and swing period of the test body, so the required flow of the hydraulic drive system will not change. As the mass of the test body changes, the required displacement of the hydraulic pump remains unchanged. Therefore, when the mass of the test body changes within the range of ± 1 ‰, the selected components still have the ability to drive the system to operate normally.

3.2.2 Radius deviation
In the case of other parameters taking standard values, when the radius R of the test body changes between -1% to + 1%, the main parameters of the system change as shown in Figures 6 to 9.
It can be seen from Figure 5 to 9 that the larger the test body radius, the larger the moment of inertia, the longer the swing period, and the smaller the maximum swing angular velocity. However, due to the increase in the diameter of the test body, the transmission ratio between the test body and the drum of the lower supporting device increases, which results in an increase in the drum rotation speed and a larger hydraulic system flow rate, resulting in an increase in the displacement of the hydraulic pump. And when the radius changes to the largest, the required displacement of the hydraulic pump still does not exceed the rated displacement of the selected hydraulic pump, ensuring that the hydraulic drive system still has the ability to operate normally under the most changed conditions.

3.2.3 Impact of comprehensive deviations
From the above analysis, it can be found that the change in the mass of the test body only changes the maximum static angle, and the demand for the flow of the hydraulic drive system has not changed. As the radius of the test body and the lateral stability height increase, the demand for the hydraulic drive system flow increases. It is calculated that when the cabin segment radius increases by 10% and the lateral stability height increases by 10%, the displacement that the hydraulic pump needed is the largest. However, the shape of the test body has a greater influence on the rocking motion process. When the roundness error of the test body's support part is too large, the outer surface is uneven, or the coaxiality of the front and rear support sections is too large, all will lead to the failure of the supporting roller of the lower part of the test device to fully fit with the test body. The error of the shape of the test body makes the test body inevitable to impact and vibrate with the supporting rollers during the swing process, which causes the test body to move erratically. Once the impact occurs, the impact will be large, which is likely to cause damage to the load bearing device and even affect the bottom pressure of the pool. Once the impact occurs, it may cause damage to the bottom of the pool.

4. Analysis of the influence of installation error on driving capacity

4.1 Position installation error
The test body position installation error is mainly composed of three parts: the axial installation position error of the load bearing device, the test body rope groove position error, and the pool wall pulley installation position error. According to the maximum error estimation, the actual position will deviate from the limit to 3 times the theoretical value. As shown in Figure 10, considering the extreme working conditions, under these conditions, the maximum inclination angle of the steel wire rope caused by the installation position error is about 3°. When all the force steel wire ropes are acting with the maximum output force at the same time, the maximum axial force will be generated. Because the contact surface between the bracket baffle and the cabin section is covered with copper plate, according to its friction coefficient, the maximum frictional moment between the bracket baffle and the cabin section still meets the safety limitation, which has less impact on the system.
4.2 Waterline position installation error

Waterline position error will cause the negative buoyancy of the test body to change. If the tolerance of the waterline position is ± 100mm, the range of negative buoyancy will vary from 80% to 120%. According to the maximum negative buoyancy calculation, two supporting rollers (A, B) The force diagram is shown in Figure 11. In addition, the change in negative buoyancy will also affect the Coulomb friction torque on the test body. As shown in Figure 12, the maximum Coulomb friction torque is much smaller than the maximum output torque of the hydraulic motor drive system. Therefore, the waterline position is within the error range of ± 100mm, which has almost no effect on the system operation.

Through the above analysis, the system selects the type of wobble period than the wobble period shown in the theoretical calculations and simulation results, leaving a certain margin. In the case of a certain deviation in construction and installation, the system can still ensure normal operation; The construction deviation has little influence on the driving ability of the system, but the large deviation of the size and structure of the test body will affect the sway process, easily cause vibration and shock, affect the life of the load bearing device, and even cause damage to the load bearing device.

Based on the analysis of test device construction deviation and scalability, this paper gives corresponding improvement strategies and provides useful guidance for construction and operation.

Acknowledgement

This study was supported by “The National Key Research and Development Program of China: Research on the technology of nuclear power plant of floating nuclear plants” (2017YFC0307800/06).
References

[1] Cenwei, S., Jianqi, Q., Ruiguang, L., (2007) A Novel Self-Commutating Low-Speed Reluctance Motor for Direct-Drive Application. IEEE Transactions on Industry Application., 43(1): 57-58P

[2] Honda, H., Nishimura, H., Miyamoto, S. (2003) Processing of multi-monochromatic x-ray images from indirect drive implosions at OMEGA. Review of Scientific Instruments. 74(3): 1951-1953