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Exploit of Shipping Auxiliary Swing Test Platform

Jia WANG[1, a], Dao-hua LU[1] and Song-lian XIE[1]

[1]School of Mechanical Eng., Jiangsu University of Science and Technology, Zhenjiang, Jiangsu, China, 212003

[a]wjjzhb@qq.com

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Abstract. Shipping auxiliary swing test Platform is a kind of test device which can complete performance tests of the ship auxiliary equipment by simulating the motion of ships in the laboratory environment. This article presented a swing test-bed with high torque dynamic load of three-degree of freedom (3-DOF), simulated mainly the motion of rolling, pitching and heaving in a specific sea state. Put forward some comparison and design of the structure schemes against the requirement of high torque load, choose the best scheme according to the test requirement, and introduce some key accessories design of the made reliability accounting on the key mechanical structure of the swing test-bed.

Introduction

As a spatial parallel mechanism, swing test bench is widely used to simulate the attitude of warship and vehicle, which has very high application value in national defense and civilian use. At present, there are many studies on parallel platform with six degrees of freedom, but only the movement with some degrees of freedom is needed in many occasions. It is the practical necessity that this paper is based on and develops a novel parallel swing test bench with three degrees of freedom, which is used to simulate that ships pitch and heave in a particular sea state on land, and form general development environment for ship motion control. In this environment, it can evaluate prototype and test its performance, providing a series of reasonable parameters for product, reducing the times of experiment on the sea, cutting down the experimental cost, and shortening the development cycle, which ensures the safety of sea trial.

Structure analysis is very important for the research on the parallel mechanism. According to requirements of simulation test this paper choose the optimal structure scheme; For improving the safe factor, the installation accuracy and service life of swaying test platform, this paper also study on some key accessories of swing test bench.

Structural design solution

Marine auxiliary machinery swing test bench mainly simulate the ship's roll, pitch and heave motion and then verify the performance of the ship boat equipment. The characteristics are that the load is relatively large and boat equipment has large torque against swing test bench, and the heave motion has a large displacement requirement. This requires the swaying test bench has higher strength and stiffness.

In order to enhance the strength and stiffness, the parallel mechanism with passive chain limb is chosen while designing. It is easy to design the configuration of the parallel mechanism according to the characteristics of construction requirements. If the demand of the degrees of freedom of the parallel mechanism known, the specific construction of passive chain limb can be given out, while the mechanism form of active chain can be defined by the driving form. The design comparison shows that isosceles right-angle three-cylinder with the cantilever located at third load boundary can

most surely meet the requirement of strength and stiffness under the limitation of the test-bed with three-degree of freedom.

The design requirements of the test-bed: the displacement of swing bed heaves is ±1m; the transverse rolling range of swing bench is 15^{o}, the longitudinal rolling range of swing bench is 10^{o}, the max angular velocity is 2°/*S*; the load suspending is 3 tons (the fixed thing that the swing test-bed installs is 3000 kg. It has a rectangular cantilever with 3 meters height and 6 meters length, hanging 3 tons things.

Three structure schemes are compared and analyzed: the first one is isosceles right-angle three-cylinder without the middle column; the second one is isosceles right-angle three-cylinder with the middle column; the third one is isosceles right-angle three-cylinder with the middle column which uses the Intermediate balance cylinder. Finally the best one will be chosen.

The schematic of a swing test-bed that uses isosceles right-angle three-cylinder parallel mechanism without middle column shows in Fig.1.

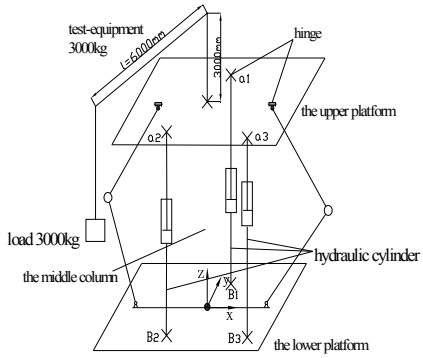

Fig.1 The structure schematic of a swing test-bed with three-degree of freedom(1)

The test-bed is composed of an upper moving platform, three telescopic supporting mechanisms and the lower moving platform. The three telescopic supporting mechanisms use hydraulic cylinder standard parts. The upper platform adopts welded rectangular steel and steel plate, and the lower platform adopts welded channel steel and steel plate. Connections of both ends of the three hydraulic cylinders are Hooke.

The schematic of a swing test-bed that uses isosceles right-angle three-cylinder parallel mechanism with middle column or Intermediate balance cylinder shows in Fig. 2.

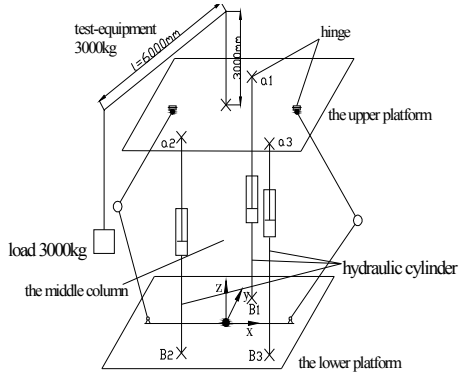

Fig.2 Structure schematic of three degrees of freedom swing test bench(2)

The swing test bench mainly adopts force analysis of structure in this article , choose the best scheme from three design schemes according to the comparison .

According to the character of the parallel structure of isosceles three cylinders can be seen that two hydraulic cylinders under pressure, one hydraulic cylinder under tension and the blinds are not affected by external force.

According to the load of test bench and distribution of hydraulic cylinder in the structure schematic, it shows that when the test-bed is moving, hydraulic cylinder bear the maximum tension under the transverse rolling motion (taking into account that three hydraulic cylinders of the swaying test platform in the dynamic operation will have a very small offset, with minimal impact on the calculation result, so it can be neglected).

The first scheme: using isosceles right-angle three - cylinder without middle column.

Swaying test bench without middle column fixed, it is easy for the hydraulic cylinder to emerge the shift phenomenon under the transverse rolling motion and the longitudinal rolling motion of swaying platform, which increase the requirement of stiffness and strength of hydraulic cylinder, reducing the accuracy of the experiment of the rolling test platform.

Second schemes: isosceles right-angle three - cylinder with the middle column.

According to the force and the torque balance equations:

$$\begin{cases} F_1+F_2+F_3=F=m_1+m_2+m_3 & (1) \\ -1.25F_1+1.25(F_2+F_3)=T_1+T_2 & (2) \\ 1.25F_2\cos\alpha-1.25F_2\sin\alpha-1.25F_3\cos\alpha-1.25F_3\sin\alpha=T_{2x}+T_4+T_5+T_x & (3) \end{cases}$$

The support reactions of the upper platform in a_1, a_2, a_3 from the hydraulic cylinders respectively: F_1=-0.4×10^4N, F_2=1.413×10^5N, F_3=2.27×10^4N. Where

F_1 -- the support reactions in point a_1.

F_2 -- the support reactions in point a_2.

F_2 -- the support reactions in point a_3.

T_1 -- the torque of upper platform from suspended load of cantalever,

T_2 -- the torque of upper platform from cantalever of boat equipment,

T_{2x} -- orque of the rotating shaft x from cantalever,

T_4 -- the torque of the rotating shaft x from upright column of boat,

T_5 -- the torque of the rotating shaft x from load of cantalever,

T_6 -- the total torque from platform around the rotating axis,

Third schemes: isosceles right-angle three-cylinder containing middle upright column of the intermediate balance cylinder.

The middle column use the intermediate balance cylinder to support the load excludes the weight of the upper platform, the three hydraulic cylinders are used to balance the weight of the load.

Force analysis diagram is shown in Fig. 3:

According to the force and the torque balance equations:

$$\begin{cases} F_2+F_3+F_1=\mathrm{F}=m_2+m_3 & (4) \\ -1.25F_1+1.25(F_2+F_3)=T_1+T_{2y} & (5) \\ 1.25F_2\cos\alpha-1.25F_2\sin\alpha-1.25F_3\cos\alpha-1.25F_3\sin\alpha=T_{2x}+T_4+T_5+T_x & (6) \end{cases}$$

The support reactions of the upper platform in a_1, a_2, a_3 from the hydraulic cylinder respectively: F_1=-5.4×10^4N, F_2=1.095×10^5N, F_3=0.44×10^4N.

In the second scheme, the maximum load of the rolling test platform is1.43×10^{5}N; The maximum load of the rolling test platform in the third scheme is1.095×10^{5}N. Through the comparative analysis, following the maximum benefit principle and optimization principle , the third scheme should be selected.

To the third program selected, degrees of freedom for analysis:

Four branches(three hydraulic cylinders and the middle column)apply the same constraint to the platform clearly, limiting the rotation of the Z-axis of platform, these four couples constitute a common constraint, in other words: λ=1, there are another two remaining constraints and the constraints are linear correlative, dev=0.

To be based on the considered redundant constraints of the general formula Kutzbach-Grübler:

$$M=d(n-g-1)+\sum_{i=1}^{g}f_i+v-\zeta=(6-1)\times(9-11-1)+(2\times7+4\times1)=3 \tag{7}$$

Where M represents DOF, d denotes the order number, d=6 - λ;n represents the number of components including racks; g represents the number of deputy campaign; fi represents the degree of freedom of i-th movement vice; v is parallel mechanism in the removal of polycyclic public constraint factors of the number of redundant constraints. Where ζ is the local degrees of freedom which exists in the institutions (here is 0).

Therefore, this article is three degrees of freedom parallel mechanism.

The key accessories design

Some key accessories design of a complete mechanical product often determines the mechanical life of the product, maintenance cycle, and precision machining, etc. Therefore, the design selections of some small parts are particularly important. This article is now selecting some of the more innovative key accessories to analyze and introduce.

Small spacing platform

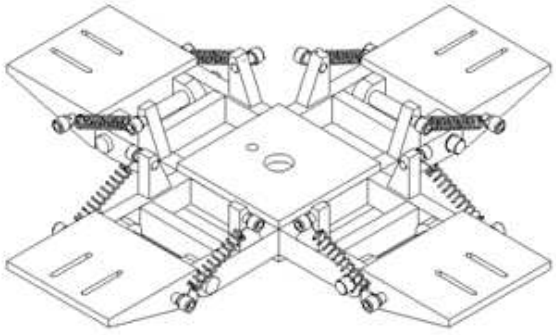

Fig.3 Schematic diagram of the small spacing platform

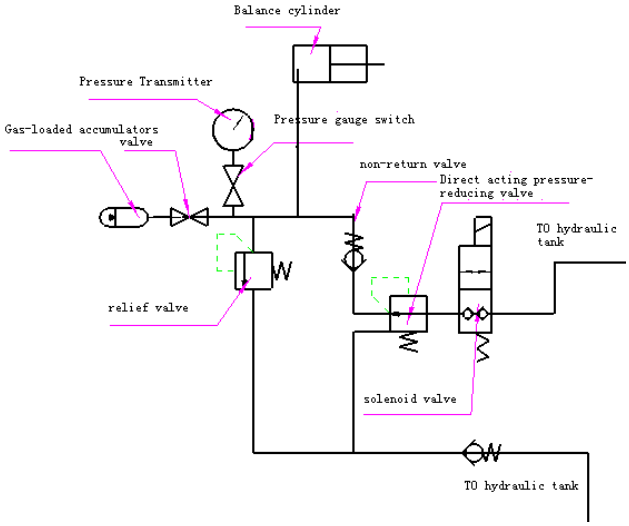

Fig.4 The hydraulic schematic of the balance mechanism

A small spacing platform consists of a round hook circumferential pressing typed normal tension spring, a mounted plate, a pivot, a ring-shield and a extending plate, installed at the top of the middle column. A small spacing platform mainly plays the role of spacing and protecting. When the roll, pitch or mixed shake of the swing test bench gets out of control, the small spacing platform can stop the movement in a certain range, getting some buffer time to save it, as is shown in Fig.3.

The Intermediate Balance Structure. A hydraulic balance circuit is a circuit which sets a certain resistance, and produces some back pressure in order to make it steadily fall down, to prevent the vertical hydraulic cylinder and vertical movement parts from falling down due to their weight. It is widely used in construction machinery, crane and some occasions with vertical movement parts.

Intermediate balance mechanism in this article uses balance valve, the hydraulic circuit, proportional valves, reversing valve, protection module, load cylinderload cylinder and the accumulator and so on, as is shown in Fig.4, which is mainly used to support the weight of the upper platform besides the load, reduce the load imposed on the hydraulic cylinder, optimize the structure, and reduce the requirements to the equipment. This paper further explains it through the hydraulic schematic of the balance mechanism.

According to the use of middle column cylinder and the accumulator, when the swing test-bed works, it produces a force used to balance the weight of the upper platform except the load, and controls oil the flow-direction and flowrate through the signal communication. When operating in the swaying test platform, we should regularly check the accumulator pressure gauge pressure loop, when the pressure is lower than the value we set, open the high pressure ball valve circuit of the hydraulic pump, start on the device for oil storage, till set value is reached and close the high-pressure ball valve and pump. In order to make the balance mechanism support the load except the weight of platform at any time.

This mechanism is the use of accumulator principle, control cylinder and the accumulator with the hydraulic cylinder swing test platform of heave and sway, balance weight upper platform of swing test platform, so as to improve speed, decrease costs and reduce the load of hydraulic cylinders ,increase the overall mechanical life.

Conclusion

In this paper, three degrees of freedom auxiliary ships swing test platform, the middle column presents a new design with a balance cylinder method. Using this method not only improves the security of the system, also reduces manufacturing costs. In addition, the method also introduces the design of some key accessories. Provides a new design method and implementation model for the future development of similar swaying test platform, shorten product exploitation time, has important reference value.

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