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Research on the synchronous vibration of the non-integral mechanism under the vibration environment

Miao Tongye[1], Du Xiangyang[2], Luo Xuan[3]

1,2,3(College of Mechanical Engineering, Shanghai University of Engineering Science, China)
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Abstract: *This article proposes and designs the internal structure of the electrical cabinet which can achieve the 3-DOF (degrees-of-freedom) motion, and making it in the horizontal vibration environment with excitation frequency of 12.5Hz.Obtaining vibrational properties of its internal structure through the Simulink simulation results, which is to said that manipulator and low-voltage electrical appliances are not in the synchronous conditions. But it is necessary to make it in a state of near synchronization to ensure the accuracy of the reliability test of the variable load load with low-voltage electrical appliances. On this issue,to achieve the desired results through the PID feedback control to further optimize.*

Key words: *electrical cabinet, Simulink simulation, PID control, synchronous vibration*

I. INTRODUCTION

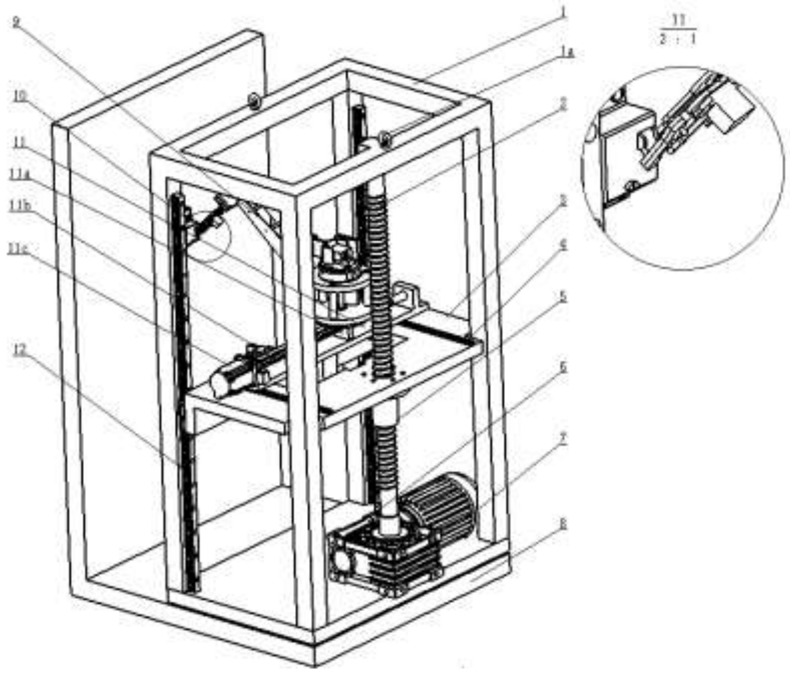
With the rapid development of science and technology, the use of machinery and equipment is more complicated. Under the influence of external excitation, it is often affected by vibration, which makes the failure mode of the machine become more and more complicated[1]. Many mechanical equipment require two or more than two parts, such as shaft, rod, cylinder piston etc, and make them in a state of near synchronization are necessary. It is not only can improve the service life of the machine, but also can provide the theoretical support for the measurement of the mechanical and kinematics of the vibration environment[2-3].According to electrical cabinet of single degree of freedom vibration system and Lagrangian mechanics analysis to establish the overall module theory of vibration dynamic model, then proving the vibration incomplete synchronization of internal structure of electric appliance cabinet (manipulator and low-voltage electrical appliance) under vibration environment though Simulink simulation. Finally,making the internal structure of electric appliance cabinet in approach of synchronous movement and providing adequate theoretical basis and guidance when we do research on the reliability test of the variable load load with low-voltage electrical appliance.

II. DESIGN OF THE INTERNAL STRUCTURE

2.1 Design Ideas

In the equipment design process, considering the structure is working in the vibration environment, the overall monolithic construction should be adopted[4].Combined monolithic construction with some modular devices to meet the synchronous requirements of the equipment in the vibration process at most extremely to a maximum extent furthest ,thus further improve the accuracy of the measurement and calculation of the tension of the manipulator and low-voltage electrical appliances.

2.2 Principle and Procedure of Equipment



1 - frame, 1a - lug; 2 - wire rod (Φ40mm); 3 - stage; 4 - Track 2; 5 -saddle ;6 - reducer holder; 7 - motor1 ;8- loading plate; 9 -manipulator8- loading plate; 9 - arm; 10 -low-voltage electrical appliances;11- Wire rod slider mechanism slider mechanism; 11a -Wire rod (Φ15mm);11b - motor 2;11C - slider;12 -guide1

FIG 1 Schematic diagram of the internal structure

The working principle of the internal structure of the electrical cabinet and the whole action process are as follows: In the case of the position height of the low voltage electrical apparatus which is known to crawl, the PLC programming module prompted 110V driver drive motor (7) drive reducer (6) of deceleration, speed reducer by coupling connected to drive the screw rod (2) causes it to rotate so as to drive the load table (3) on the movement, realize the manipulator Z axis can be adjusted and controlled; reach the specified height, motor (7) stop working, the motor (11c) began to work by coupling connection of the screw rod (11b) rotates to drive the slider (11a) and the manipulator (9) to move around, so as to realize the manipulator of Y axis adjustable control, the same, the same way, the X axis direction of the motor start work, let the screw rotation to drive the front and rear slider mechanism to achieve the adjustable control of the manipulator and the low-voltage electrical apparatus, the device ,in the process of manipulator to grasp the low-voltage electrical switch, can realize the manipulator three degrees of freedom controllable.

III. VIBRATION MODEL

The mechanical model of the whole mechanical system of the vibration is shown in Figure 2. It is mainly said that put the electrical cabinet as a whole , then divide the whole into several small modules((internal structure) and carry out the primary and secondary mechanical analysis (manipulator and low-voltage electrical mechanical analysis) to obtain the difference between the output response of the modular structure when they are in Synchronous motion state.

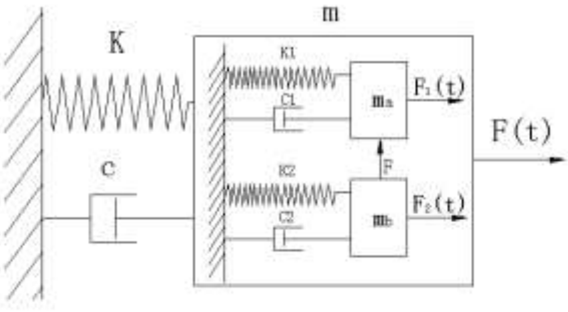


FIG 2 Vibration dynamics model

The vibration mechanical model can be directly derived from the Lagrange mechanics principle. In this paper, the mathematical model of the reference documentation is given [5], and the mathematical expression of the simplified model is given.

$$m\ddot{x}+c\dot{x}+kx=F(t)$$

$$m_a\ddot{x}+c_1\dot{x}+k_1x=F_1(t)$$

$$m_b\ddot{x}+c_2\dot{x}+k_2x=F_2(t)$$

m , m_a , m_b represent the quality of electrical cabinet and manipulator and low-voltage electrical machine ; $\ddot{x}$, $\dot{x}$ express X-axis acceleration and velocity; c , c_1 , c_2 , k , k_1 , k_2 express X axis direction of the corresponding damping and stiffness; $F(t)$, $F_1(t)$, $F_2(t)$ express corresponding response.

IV. VIBRATIONAL COMPENSATION CONTROL

In the horizontal vibration of the electrical cabinet, the electrical cabinet and the internal structure are considered as a whole, and the low-voltage electrical equipment and the manipulator should be in synchronous vibration , but in practice, the low-voltage electrical equipment and electrical cabinet are not a whole body, instead, on the electrical cabinet with a bolt and nut and the manipulator is fixed on the lead screw slide with large gap which is in the non direct contact with the motor cabinet. To sum up, in the horizontal vibration of the electrical cabinet, the low-voltage electrical equipment and the manipulator are not completely in synchronous state or even produce a large deviation. Thus, the accuracy of traction force(F) will be greatly affected in the research of low voltage electrical apparatus reliability test. In order to solve this problem, PID feedback control, which can be very good to prevent the generation of errors is a better method.

4.1 Simulink Simulation Analysis

By the differential equations of motion $\ddot{x}=-c\dot{x}/m-kx/m+F/m$, the output displacement response can be obtained by the appropriate two integrals and the simulation model can be built by using the basic module of Simulink. The parameters of simulation model of vibration:

$m_1 = 15kg$, $k_1 = 8kN$, $c_1 = 200\,N \cdot s/m$, $m_2 = 20kg$, $k_2 = 6kN$, $c_2 = 200\,N \cdot s/m$, $f = 12.5Hz$ and shown in FIG 3.

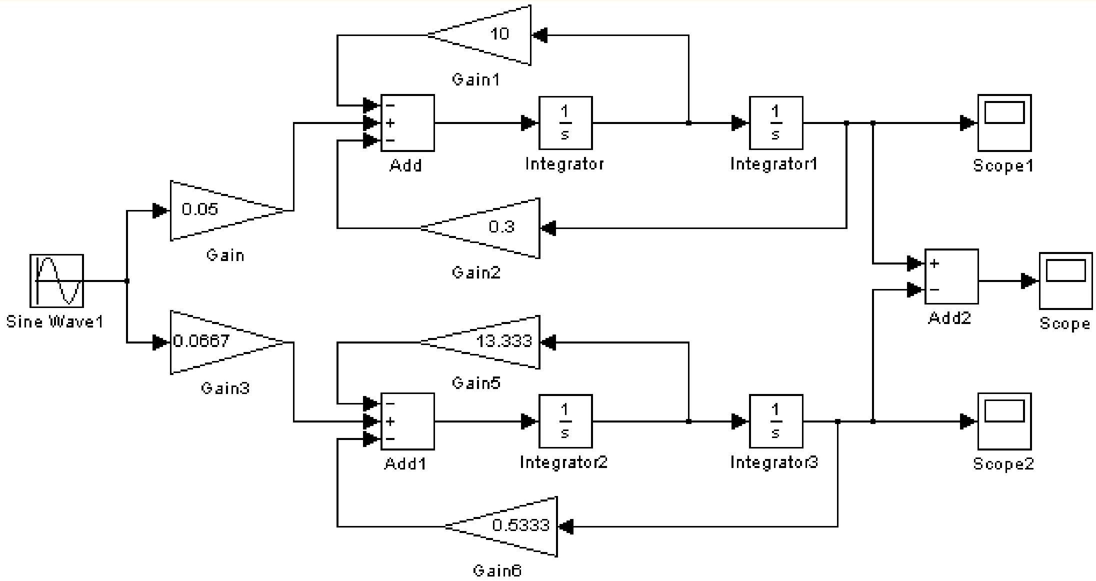
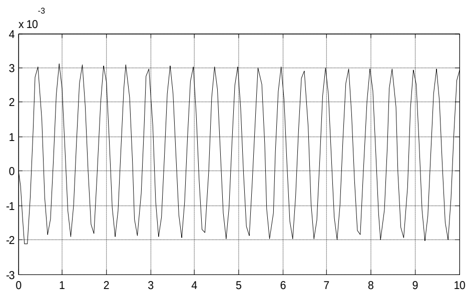


FIG 3 Simulation model of the system

To make the manipulator and the low-voltage electrical equipment reach the synchronous state, thus they must have the same displacement, velocity and acceleration and the above model is only for the displacement of the corresponding simulation. In the simulation process, put the manipulator and low-voltage electrical in the same vibration environment, and give the same external excitation force to simulate. In the pick of the simulation results, the analysis of the results is needed to wait for the vibration of the smooth to prevent the fluctuation of data at the initial stage of the vibration, and the data acquisition is not accurate. Simulation results are shown in FIG 4’5'6.



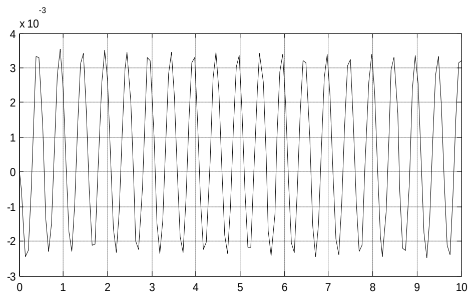


FIG 4 Low-voltage apparatus’ displacement curve   FIG 5 Manipulator’ displacement curve

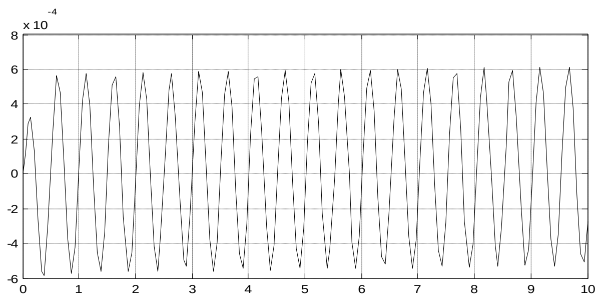


FIG 6 Displacement difference curve diagram

From the above simulation results can be seen, in the process of vibration, even if given the same external excitation power cabinet, the vibration displacement of its internal manipulator and the low-voltage electrical vibration displacement curve diagram is still a big difference, as shown in FIG 6.

4.2 PID feedback control

The manipulator and the low voltage-electrical apparatus must be required to be in a state of synchronous vibration during the research of low voltage electrical apparatus reliability test. And the simulation results of Figure 6 can be known，there is still a large displacement error between them. In order to ensure the accuracy of the measurement, the PID feedback regulation is needed to make the displacement difference between the two is almost zero.

PID controller is a linear regulator and it compares the setting value with the actual output value to constitute the control deviation. $e = r - y$, e refer to deviation, r refer to setting value, y refer to the actual output value. To control the controlled object though the control quantity which is made up of the proportion, integral, differential with linear combination [8-9].And then the actual output value is fed back to the setting value, move in circles, until the system reaches the design requirements.

In FIG 7, A represents the manipulator of the horizontal vibration displacement curve, B represents the low-voltage electrical level of vibration displacement curve.PID1 and PID2 regulators are adjusted to adjust the corresponding displacement and then to set up the corresponding adjustment parameters to obtain the optimal results. Debug results are shown in FIG 8.

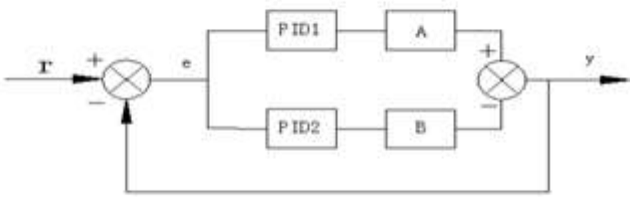


FIG 7 PID feedback control diagram

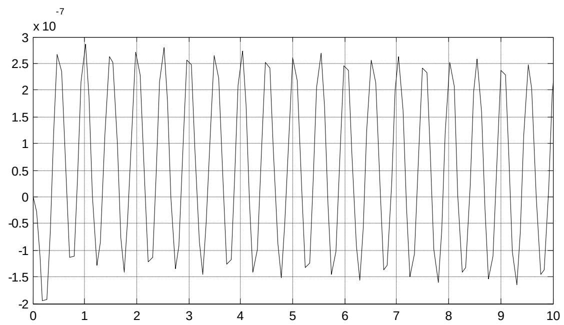


FIG 8 PID adjustment of displacement difference curve

Compared FIG 6 with FIG 8, we can find that the displacement of the manipulator and low- voltage electric appliance difference curve gradually close to the x axis under the control of double PID regulator, that is to say the trend ,from incomplete synchronization to gradual synchronization, become more and more obvious In horizontal vibration. But fully synchronous vibration state is difficult to reach because of the complexity and unpredictability of vibration [10], the design of PID model and parameters should be improved [10].

V. CONCLUSION

In the field of vibration machinery, it is a difficult problem to realize the synchronous vibration state of complex mechanism [11].In this paper, a design of electric cabinet structure is presented which can be used to do research and analysis on the horizontal vibration of the vibration model. With the PID feedback control and Simulink simulation, the model gradually tends to be stable (the state of near synchronous vibration), and thus provides sufficient theoretical basis and guidance for the research on the reliability test of low voltage electrical apparatus, which has a good theoretical and practical significance.

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