Study on dynamic characteristics of bearing-rotor system under ship sway condition

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Abstract: On condition that pans and tilts, ship bearing rotor system stability and security, as the change of ship swaying amplitude have influence, based on independent research and development of guangzhou maritime college design of vertical and horizontal swing test bench, simulate the real working condition of ships at sea, in the performance of bearing rotor system under rolling condition were studied. LMS_TEST.LAB modal tester software was used to analyze the dynamic characteristics and collect the experimental data of the bearing rotor system for analysis and research. In this paper, the influence of period and amplitude on the dynamic characteristics of the bearing-rotor system and the influence on the axis trajectory of the bearing-rotor system under different working conditions are analyzed mainly under the rolling condition.

1. Introduction
Ship sailing on the sea, the sea wind wave factors will cause the ship longitudinal and lateral swaying motion occurs, the rotor - bearing system of ship power equipment fixed on the ship hull longitudinal and lateral swaying motion occurs when the low frequency and large displacement of sliding bearing vibration is passed to the supporting shaft, and then passed to the power device of the rotor, as shown in figure 1. As an important power plant system of a ship, rotor-rotor system is a key component of ship movement. Therefore, it is necessary to analyze and study the dynamic characteristics of the rotor-rotor system under swinging motion for the safe and stable navigation of a ship, which has very important practical significance[1].

Fig. 1 Schematic diagram of ship coordinate system and bearing-rotor system
When rocking motion occurs in Marine power plant system, the bearing-rotor system will be affected by oil film force, unbalance excitation force, implicated inertia force, gyro moment and so on. Ships' rocking motion is characterized by long period, large amplitude, frequency etc[2]. It is very
important to study the dynamic characteristics of the bearing-rotor system of the ship power plant when the ship swings in longitudinal and transverse motion\footnote{3}. In this paper, LMS\_TEST. LAB modal tester analysis software is used to analyze the dynamic characteristics of the bearing-rotor system and collect the experimental data of the bearing-rotor system for analysis and research. Under the rolling condition, the influence of period and amplitude on the dynamic characteristics of the bearing-rotor system and the influence on the axis trajectory of the bearing-rotor system under different working conditions were analyzed\footnote{4,5}.

2. Dynamic characteristics of bearing-rotor system

Ships sailing at sea mainly consist of rolling and pitching. This paper mainly analyzes the dynamic characteristics of a ship's bearing-rotor system under rolling condition. The ship's rolling refers to the rolling motion of the hull rotating around its longitudinal axis along the tangent direction of the track. Its characteristic is that in the process of rocking, the direction and magnitude of the gravity component in the direction of X axis and Y axis will periodically change with the hull sway, which leads to the periodic change of the bearing load acting on the sliding bearing with the hull sway. Let the frequency of hull sway be $\omega_x$, unit HZ; The angular displacement of the swing is $\theta_{1Z}$, unit rad; The oscillation velocity is $\dot{\theta}_{1Z}$, unit rad/s, The acceleration of the swing is $\ddot{\theta}_{1Z}$, unit rad/s$^2$, The oscillation amplitude is $\theta_{Z0}$, unit rad, The initial phase is $\phi_{Z0}$, unit rad. In general, when the ship is in rolling motion, $\theta_{1Z} \neq 0$, $\dot{\theta}_{1Z} \neq 0$, $\ddot{\theta}_{1Z} \neq 0$, $\theta_{Z}$ and $\dot{\theta}_{Z}$ Changes while the other motion parameters are zero.

$$\theta_{1Z} = \theta_{x,m} \sin \left( 2\pi \omega_x t + \phi_{x,0} \right) \quad (1)$$

$$\dot{\theta}_{1Z} = \theta_{x,m} 2\pi \omega_x \cos \left( 2\pi \omega_x t + \phi_{x,0} \right) \quad (2)$$

$$\ddot{\theta}_{1Z} = -\theta_{x,m} (2\pi \omega_x)^2 \sin \left( \omega_x t + \phi_{x,0} \right) \quad (3)$$

The above formula is the change law of displacement, velocity and acceleration when the ship is rolling laterally, that is, the swing law of the ship's rolling motion.

3. Dynamic characteristics analysis of ship swinging motion bearing-rotor system

3.1. Influence of swing amplitude on dynamic characteristics of bearing-rotor system

When the ship rolls, the rotor speed is selected as 2800rpm, the period of rocking is 8s, and the amplitude of rocking is selected as $10^\circ$, $13^\circ$ and $15^\circ$. Lab modal tester analysis software was used to derive vertical and horizontal images of the eddy current sensor, as shown in Fig 2.

![Fig. 2 spectrum of vertical and horizontal eddy currents with different amplitudes](image)

It can be found from the above figure that in the rolling condition, when we observe the output analysis diagram of the eddy current sensor and change the swing amplitude with the same period, the amplitude change of the bearing-rotor system in the horizontal direction is more obvious, while the change change in the vertical direction is relatively small. Therefore, the data derived from the horizontal eddy current sensor is mainly analyzed, as shown in Fig 3.
By calculation, when the amplitude is 10°, the amplitude of the bearing-rotor system is 0.215mm/s, and when the amplitude is 13°, the amplitude of the bearing-rotor system is 0.225mm/s. When the amplitude is 15°, the amplitude of the bearing-rotor system is 0.235mm/s. It can be found that under the condition that the period does not change, the amplitude of the bearing-rotor system gradually increases with the increase of the rolling amplitude.

3.2. Influence of swing period on dynamic characteristics of bearing-rotor system

When the ship rolls, the rotor speed is selected as 2800rpm, the swing amplitude is 15°, and the swing period is selected as 8s, 10s, and 12s. Lab modal tester analysis software was used to derive the vertical and horizontal images of the eddy current sensor, as shown in Fig. 4.

It can be found from the above figure that in the rolling condition, when we observe the output analysis diagram of the eddy current sensor, when the amplitude is the same and the swing period is changed, the bearing-rotor system changes significantly in the horizontal direction, while the change in the vertical direction is relatively small. Therefore, the data derived from the horizontal eddy current sensor is mainly analyzed, as shown in Fig 5.

By calculation, when the period is 8s, the amplitude of the bearing-rotor system is 0.235mm/s, and when the period is 10s, the amplitude of the bearing-rotor system is 0.225mm/s. When the period is 12s, the amplitude of the bearing-rotor system is 0.220mm/s. It can be found that the amplitude of the bearing-rotor system gradually decreases with the increase of the rolling period under the condition that the amplitude remains unchanged.

3.3. Influence of different working conditions on the axle center trajectory of the bearing-rotor system

The rotation speed of the rotor is 2800rpm to analyze the change of the rotor's axis trajectory. Firstly, the rotor's axis trajectory is analyzed under the horizontal working condition (0°), as well as the tilt of 10° and 15°. Then, the rotor's axis trajectory with the swing amplitude of 10° and 15° is selected for
the period of 8s, 10s and 12s. Lab modal tester analysis software was used to derive the vertical and horizontal data analysis of the eddy current sensor and generate the rotor axis orbit diagram, as shown in Fig. 6.

![Fig. 6 The trajectory of rotor axis under different working conditions](image)

According to the analysis, when the amplitude is 10° and the period is 8S, the maximum horizontal distance between the two ends of the rotor is 0.45mm, and the maximum horizontal distance between the two ends of the rotor is 0.50mm. When the amplitude is 13° and the period is 8S, the maximum horizontal distance between the running ends of the rotor is 0.46mm, and the maximum horizontal distance between the vertical ends is 0.51mm. When the amplitude is 15° and the period is 8S, the maximum horizontal distance between the running ends of the rotor is 0.46mm, and the maximum horizontal distance between the vertical ends is 0.51mm.

When the amplitude is 10° and the period is 12S, the maximum horizontal distance between the running ends of the rotor is 0.47mm, and the maximum horizontal distance between the vertical ends is 0.50mm. When the amplitude is 13° and the period is 12S, the maximum horizontal distance between the two ends of the rotor operation is 0.46mm, and the maximum horizontal distance between the vertical ends is 0.51mm. When the amplitude is 15° and the period is 12S, the maximum horizontal distance between the two ends of the rotor operation is 0.49mm, and the maximum horizontal distance between the vertical ends is 0.52mm.

The analysis shows that the period is the same. First, the trajectory diagram of the rotor's axis center under the tilt condition is established, and then the trajectory of the rotor with different amplitude values under the swing condition is established. Through the analysis, the operating
displacement of the trajectory of the axis center increases gradually with the increase of amplitude.

4. **Summarize**

By simulating the real working conditions, the dynamic characteristics of the bearing-rotor system were analyzed, and the following conclusions were drawn:

1. With the increase of rolling amplitude, the amplitude of the bearing - rotor system increases gradually when the ship's rolling period remains unchanged.
2. With the increase of rolling period, the amplitude of the bearing-rotor system decreases gradually when the ship's rolling amplitude remains unchanged.
3. Under the swing condition, the influence of different amplitude values on the rotor's axial track is analyzed. As the amplitude increases, the operating displacement of the axial track gradually increases.

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