Study on dynamic characteristics of rotor-bearing system under pitching condition

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Abstract: In many cases, ships will encounter special conditions, such as bad sea conditions, and the effect of various disturbance factors, such as wind and waves, will cause low-frequency longitudinal and transverse rocking motion of ships. This would affect the rotor-bearing system of the power plant, which is directly attached to the hull of the ship, and would roll along with the hull in the same longitudinal and transverse motion. This will have a significant impact on the stability of the rotor bearing system of the ship power plant and the safety of the ship. In this paper, a rotor-bearing test rig is mounted on a multi-degree-of-freedom swing test rig simulating sea conditions. The multi-degree-of-freedom rocking test bed simulates sea conditions. The rotor-bearing test bed is equipped with an eddy current sensor and an acceleration sensor to obtain experimental data. The programmable loader is used to control the rotor speed so as to carry out the experiment process at different speeds. Finally, the dynamic characteristics of rotor-bearing system under swinging condition are obtained.

1. Introduction
When a ship sails at sea, it will always encounter some special conditions, such as bad sea conditions. Under the action of wind, wave, current and other factors, the ship will experience low-frequency longitudinal and transverse rocking motion. The foundation of the rotor-bearing system of the ship's power device is fixed on the ship's hull. The longitudinal and transverse rolling motion of the hull caused by wind waves and other factors will also produce low-frequency and large-displacement vibration, which will be transmitted to the sliding bearings through the foundation, and then to the rotor of the power device. Compared with the high-speed rotation of the rotor of the ship power plant, the vibration frequency of the longitudinal and transverse rolling motion of the ship hull is far lower than the rotating speed of the rotor of the ship power plant, but these vibrations will still affect the whole rotor-bearing system[1].

They will first pass through the foundation of the system to the sliding bearing, have an impact on the dynamic characteristics of the sliding bearing, and then through the sliding bearing oil film force transfer to the rotor, and finally have a significant impact on the vibration characteristics of the entire rotor-bearing system.

These influences have significant influence on the stability of the rotor-bearing system and the safety of the ship. Therefore, for the rotor-bearing system of the ship power plant under the action of longitudinal and transverse rolling, it is essential to consider the influence of the ship hull's own longitudinal and transverse rolling.
2. Ship longitudinal rocking dynamic model

Usually when ships sailing the sea encounter severe sea condition and swaying motion occurs, sailing ships sailing speed, change direction, swaying motion of ship hull is a complex movement in 3 d space, because at this time, not only around the axis of rotation movement, hull also coordinates with the change of position, velocity and acceleration[2]. In this paper, we mainly discuss the ship's pitching, that is, the rocking motion in which the ship rotates about x, as shown in Figure 1.

![Ship model and sway experiment](image)

Fig 1. Ship model and sway experiment

In this paper, a series of effects of ship pitching motion on ship rotor-bearing system are analyzed. By comparing with or without pitching motion, the influence of rotor-bearing system[3] under different rotational speeds and different swing periods is studied.

In this paper, Frontback diagram and FFT diagram in analysis software of LMS modal tester are used to analyze the changes of rotor-to-bearing system with or without pitching motion under pitching motion. The influence of pitching motion on rotor motion attitude under multiple speeds is studied by using near-acceleration analysis, time-domain response and spectral response. Finally, the influence of amplitude and frequency ratio of pitching motion on the dynamic characteristics of rotor system under certain system parameters is discussed. Analysis of dynamic characteristics of ship pitching bearing - rotor system[4].

3. Analysis of dynamic characteristics of ship pitching bearing - rotor system

3.1 Influence of different rotor speeds on rotor-bearing system under the same longitudinal yaw condition

When the ship pitches, the swing amplitude of pitching movement is 18°, the swing period is 8s, and the rotor speeds are 2000rpm, 2400rpm and 2800rpm respectively. Using the LMS modal tester[5] analysis software, the vertical and horizontal spectrum of the eddy current sensor can be displayed, as shown in Figure 2.

![Spectrum of vertical and horizontal eddy currents at different rotor speeds](image)

Fig2. Spectrum of vertical and horizontal eddy currents at different rotor speeds

According to the above figure, we can see from the output analysis diagram of the eddy current sensor in the longitudinal yaw condition.

When the rotor speed is at 2000rpm, the eddy current data fluctuates significantly under the
condition of 8s periodic pitching. This reflects that the distance between the sensor and the rotor changes significantly, and the rotor with a speed of 2000rpm is greatly affected by the working condition.

When the rotating speed is 2400rpm, the eddy current data fluctuates significantly. This reflects that the distance between the sensor and the rotor changes greatly, and the rotor with a speed of 2400rpm is greatly affected by the working condition.

When the rotating speed is 2800rpm, the eddy current data will fluctuate slightly. This reflects that the distance between the sensor and the rotor changes little, and the rotor with a speed of 2800rpm is less affected by the working condition.

Therefore, the influence of changing the rotor speed on the rotor-bearing system is relatively large. It can also be seen from the figure that under the longitudinal yaw condition, the influence on the rotor in the vertical direction is more obvious than that in the horizontal direction. The smaller the rotor speed is, the more obvious the influence of the rotor system is under the longitudinal sway condition.

3.2 Influence of different pitching conditions on near acceleration of rotor-bearing system

A near acceleration sensor is arranged in the part close to the motor on the rotor-bearing test bench. Select the vertical sway Angle of 18°. First, Frontback diagrams with rotor speeds of 2000rpm, 2400rpm and 2800rpm when the pitch is 18° are analyzed. Then, Frontback diagrams with rotor speeds of 2000rpm, 2400rpm and 2800rpm are selected for periods of 8s and 12s. Using the LMS modal tester analysis software, the data analysis of the near acceleration sensor can be displayed, and the corresponding Frontback diagram generated is shown in Figure 3.

According to the analysis in the above figure, when the rotor-bearing system is in the condition of 18° pitch, because the near acceleration sensor is relatively close to the motor and is affected by the
motor, the change of near acceleration is irregular, and the near acceleration reflects the vibration of the rotor. With the increase of rotor speed, the near acceleration also increases.

Under the condition of pitching 18°, the near acceleration will change periodically, and the period of change is about 12s. The periodic variation is obvious at the rotor speeds of 2000rpm and 2800rpm, but not obvious at the rotor speeds of 2400rpm.

4. Conclusion
The dynamic characteristics of rotor-bearing system were analyzed by simulating the real longitudinal sway condition with a swing test bed, and the following conclusions were drawn:
(1) The control swing amplitude is 18°. Under the condition that the swing period is not changed, the rotor-bearing system is less affected by the working condition as the rotor speed increases.
(2) When the control swing range is 18°, the vibration of the rotor-bearing system will form periodic changes with the longitudinal sway condition, and the period of such periodic changes is about 12s.
(3) When the control swing amplitude is 18°, the periodic variation of the vibration of the rotor-bearing system will be affected by the irregular rotor speed.

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