Research on Stability of Shafting Under Two Kinds of Impact Load

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Abstract: The influence of rub-impact loadsupon the stability of shafting is directly related to the damage of ship propulsion system, so the numerical simulation and experimental technology is applied to the studyon stability of ship shafting under rub-impact load. Based on the dynamics model of stern shaft - oil film - stern structure system, the amplitude-time response curve are obtained by the numerical simulation. On the basis of theoretical researches, the tests of stability time under two kinds of loads are carried out. In addition, the effective method to shorten the shafting stability time under rub-impact load is obtained that are provided for the safe operation of shafting.

1 INTRODUCTION

Ship in the voyage, affected by the harsh environment, the hull under external forces will produce uneven deformation and random movement, resulting in hull deformation, bearing oil film whirling and the unstable state of shafting, So, restraining or weakening ship vibration is the key to strengthen the stability of shafting and improve transmission performance. In this paper, by numerical simulation and experimental, the variation law of ship shafting stability under different load and rotational speed is studied, the characteristics of longitudinal vibration are analyzed, and the effective method is found to shorten the time spent in restoring the stability of the rear axle system. It provides some theoretical basis for the optimization design of ship construction and reasonable installation of shafting, and strengthens the safety of ship in the course of navigation.

2 STABILITY ANALYSIS OF SHIP STERN SHAFT UNDER EXTERNAL FORCE

In view of the complex stress state of ship shafting, it has important theoretical significance and application value to carry out the research of shafting stability. There are two kinds of dynamic load on the ship shafting, one is the impact load of which the duration is very short and the energy release quickly. The other is the cyclic dynamic load of which the most common is the rub-impact load. Under the action of Impact load some significant changes may be made in the axis trajectory. Therefore, through the axis trajectory can obtain the stability of ship shafting and then judge the rationality of the shafting parameters design.

According to the idea of discrete modeling, the hull stern structure is discretized firstly, the discrete stern structure is linearly elastic, and the tail shaft system is simplified as a single disk system. So, the corresponding mechanical model is set up[1-3]as shown in Figure 1.

In Fig.1, the M1,M2 is the mass of the left and right axle neck; the M5 is the mass of disc; the C1 is the damping coefficient of the hinge at the bearing place; the C2 is the damping coefficient of the hinge at the disk; the C3 is the stern structure damping coefficient; the K1 is the elastic axis rigidity; The K3,K4,K5.is the connection stiffness of stern structure. The values of the parameters are: $m_1 = 100kg$, $m_2 = 80kg$, , $m_3 = 200kg$, $c_1 = 5000N.S/M$, $k = 5\times10^6 N/m$, $k_c = 5\times10^6 N/m$, $c = 0.2mm$, $r = 0.06mm$, $\delta = 0.2mm$, $f = 0.1$, $k_3 = 5\times10^7$, $k_4 = 5\times10^7 \pi$.

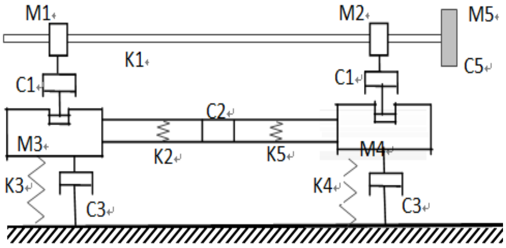

Fig.1 The mechanical model of ship shafting.

The dynamic equations of the rotor system are:

$$M\ddot{u}+(C+G)\dot{u}+Ku=F \tag{1}$$

Where in, u is the displacement array, F is the excitation force array, M is the mass matrix, G is the gyro matrix, C is the damping matrix, the K is the stiffness matrix.

3 THE SIMULATION OF STABILIZATION PROCESS UNDER IMPACT LOAD

Under normal operating conditions, the axis trajectory is most sensitive to the change of rotational speed that transferred between the convergence and the divergence state [4-7].The axis trajectory tends to deviate from the original motion trajectory when the disturbance occurs, and the time it takes to stabilize are not the same under different disturbances. Therefore, this paper mainly analyzes the change of the axis trajectory in two cases, one is the change of the axis trajectory under the condition of impact load, the other is under the condition of rubbing load.

In the course of navigation, the propeller and the hull withstand the external forces and thus the movement of the shafting are influenced. The impact load acting on the axis can be described as a rectangular pulse load shown in Fig. 2.

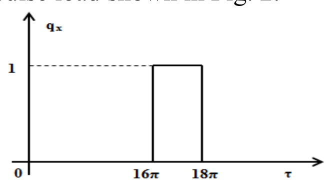

Fig.2Impulsive load fig.

$$\overline{q_x}=\begin{cases}0, & \tau<16\pi\\ 1, & 16\pi\le\tau\le18\pi\\ 0, & \tau>18\pi\end{cases}$$

$$\overline{q_y}=0 \tag{2}$$

Under the condition of impact load, with the increase of excitation frequency, the system presents the state of transition from stable motion to periodic motion and chaos motion. Accordingly, the topological structure of vibration system will be changed correspondingly. Two kinds of shafting working condition, i.e., periodic motion and chaotic motion, is analyzed and simulated of which the corresponding rotational speed is 760r/min and 800r/min. The axial-cervical vibration response is shown in Fig. 3-1andFig. 3-2in which the arrow segment indicates the time required to restore stability.

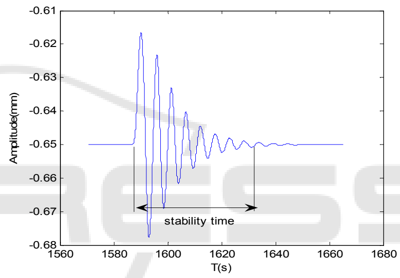

Fig3-1

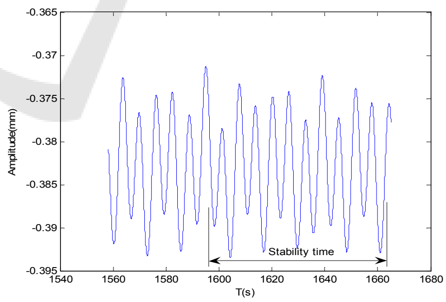

Fig3-2

Fig.3Thevibration response at speed of 760 and 800r/min.

Fig.3 show that the impact load has a certain disturbance effect on the axis trajectory. The more intense the impact load become, the longer the larger the amplitude of shafting become. As shown in Fig.3-1, the stable time is 120 when the rotational speed is 760r/min, but the stable time become 140 at speed of 800r/min as shown in Fig.3-2.Therefore, under the same impact load, choosing the appropriate rotational speed can effectively shorten the stabilizing time. And then, keeping the speed constant and changing the magnitude and duration of the impact load, the stable time under various impact loads at speed of 760r/min is measured in table 1:

Table.1 The stability time under different impact loads.

duration / Impulsive load	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
52	120.02	120.09	120.18	120.22	120.29	120.34	120.41	120.47
62	120.51	120.56	120.64	120.66	120.66	120.71	120.76	120.89
72	121.16	121.21	121.29	121.35	121.44	121.50	121.54	121.66
82	122.23	122.27	122.34	122.42	122.49	122.53	122.61	122.74

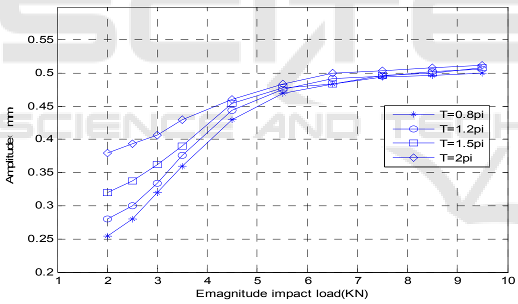

Fig 4Thestability time changed with magnitude and duration of impact load.

The curve fitting is done according to the sheets data as shown in Figure 4, that is the variation curve of stability time according to the magnitude when the duration of impact load remain constant. It can be seen that the stabilize time of shafting is different in different impact load, and the change speed of stabilize time is related to the magnitude of impact load.

4 ANALYSIS OF THE STABILITY OF THE TAIL SHAFT UNDER RUBBING LOAD

4.1 Simulation of Stability Process Under Rubbing Load

Rubbing load is a kind of working condition caused by the contact each other between tail shaft and tail bearing in the process of ship operation. When the rub occurs, the tail shaft and the tail will bear not only the collision force but also the circumferential friction force. Assuming the elastic deformation happen in the collision process, and the gap between the tail shaft and the tail bearing is δ , the rub force can be expressed as:

$$\begin{Bmatrix} P_x \\ P_y \end{Bmatrix} = -\frac{(e-\delta)k_c}{e}\begin{bmatrix} 1 & -f \\ f & 1 \end{bmatrix}\begin{Bmatrix} x \\ y \end{Bmatrix} \qquad (3)$$

Where in, $e=\sqrt{x^2+y^2}$ is the radial displacement of the shaft. When $e<\delta$,both the radial force and tangential friction are zero.

In the same way, make the friction coefficient of the rub is 0.1 and the gap δ is 0.0002, meanwhile keep the rub load and its action time constant, and change the shafting speed. When the shafting rotational speed is respectively760 and 800r/min, the stability time and the vibration amplitude under different working conditions are measured. as shown in Fig. 5-1 and Fig. 5-2.

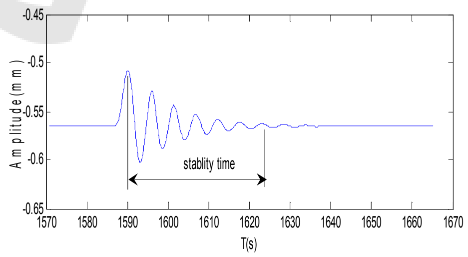

Fig 5-1

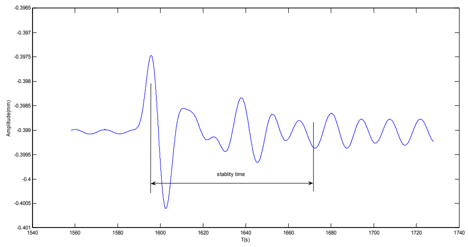

Fig 5-2

Fig.5The vibration response at speed of 760 and 800 r/min,

It can be seen that the change of the rotational speed of the ship shafting will affect the stability of the axis track when the rub load is constant. With the increase of the shafting speed, the dynamic characteristics of the bearing oil film force are changed, and the amplitude of the disturbance caused by the rub load is also increased. In addition, the changes of friction coefficient also has a certain effect to the shafting vibration. The larger the friction coefficient of rub become, that is, the bigger the spring stiffness, the more intense the longitudinal vibration of the shafting become, and the larger the vibration amplitude of shafting. Therefore, subjected to the same rub load, the stability time of the shafting system can be effectively shorten by adjusting the rotational speed and selecting the appropriate friction coefficient .

4.2 Comparison of Shafting Stability Between Two Kinds of Load

In order to compare the stability of the tail shaft under variousrub load, keeping the rotational speed unchanged and just changing the friction coefficient and elastic coefficient of rub-impact load, the stability time is observed and recorded in table 2. The data from Table 2 is shown in Figure 6.

The Fig. 6 shows the change curve of the elastic coefficient according to the increase of the friction coefficient. It can be seen that the change speed of stabilize time is different in different friction coefficients, that is, the lower the friction coefficient is, the smaller the growth rate of stabilize time is likely to be. For example, when the elasticity coefficient is 150, the shafting have the fastest recovery speed. When the coefficient of friction is less than 150, the greater the elasticity coefficient is, the greater the time needed for the stability of the shafting system, which is come to opposite conclusions when the coefficient of friction is more than 150.

Table 2TheStability time under different loads .

Friction coefficient / Elastic coefficient	0.12	0.22	0.32	0.42	0.52	0.62	0.72	0.82
150	0.750	0.664	0.607	0.565	0.531	0.503	0.482	0.470
250	0.757	0.690	0.656	0.640	0.647	0.712	0.805	0.827
350	0.764	0.713	0.698	0.715	0.804	0.838	0.850	0.850
450	0.770	0.734	0.734	0.791	0.842	0.857	0.836	0.831

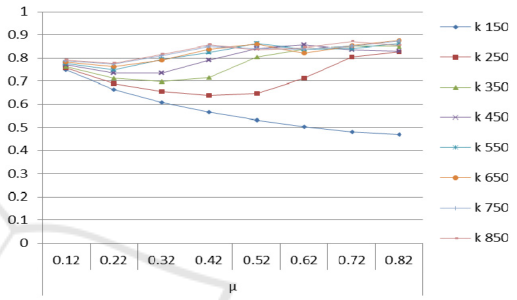

Fig 6The stability time changed with friction coefficient and elasticity coefficient

5 CONCLUSIONS

In this paper, the dynamic model of the stern shaft - oil film - stern structure system is established, and the stability characteristics after impact and rub are studied, which provides a theoretical reference for the safety evaluation of the shafting.

1. The impact and rub load will disturb the motion of ship propulsion shafting with compromise in stability which extent is related to the axis speed. In the non periodic moving region, the prolongation of the load duration will lead to the amplitude decays slowly and the ability restore the stable state of shafting become weak. On the other hand, in the periodic motion area the amplitude decays fast, and the more shaft's rotational speed deviates from the frequency area farther, the faster the amplitude decays, and the better the stability recovery of shafting system.

2. Compared under the influence of impact load, the shafting under the influence of rub load can recovered to steady state within a shorter time. By adjusting the rotational speed of shafting, the

damage effect of rub-impact on shafting can be weaken. Meanwhile, by increasing coefficient of friction will shorten the stability time of the tail shaft, and thus strengthen the stability of the ship shafting.

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