Vibration measurement method of the ship propulsion shafting

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Abstract

As an important part of the whole Marine power plant, the shaft system includes the transmission shaft, bearing and coupling between the output flange of the main engine and the propeller, connecting the main engine and the propeller. The ship's periodic excitation force (such as the main engine excitation, propeller excitation, etc.) is continuously acting on the propulsion shaft system, resulting in the steady vibration of the propulsion shaft system. Shafting vibration includes torsional vibration, longitudinal vibration and whirling vibration. When such vibration exceeds the acceptable safe range of shafting structure, it will cause various faults of shafting structure, even cause vibration of main engine body and hull, etc., which will affect the operation efficiency and safety of ships. Therefore, Therefore, it is of great significance to study the vibration of ship propulsion shafting and put forward the measurement and control method of shafting vibration.

Keywords

Vibration measurement, torsional vibration, longitudinal vibration, propulsion shafting.

1. Introduction

The vibration characteristics of propulsion shafts are the internal factors of the structure of ship's low-frequency vibration acoustic radiation spectrum. The transmission way of shafting vibration is complex and the energy exchange forms of vibration are various. It mainly includes the influence of support stiffness and damping on the dynamic behavior of shafting, longitudinal, transverse and torsional coupling vibration of multi-span statically indetermination propulsion shafting, etc. Shafting vibration research has been developed from ship engine shafting to other engine shafting, ranging from large turbine generator shafting to almost all internal combustion engine shafting and ship shafting. Propulsion shafting and hull stern are coupled structures. Longitudinal vibration of propulsion shafting is transmitted to the hull through the thrust bearing base, which causes vibration of the hull and radiates noise underwater. This is a typical problem of indirect radiation noise of propeller. The vibration of the ship propeller shaft not only affects the comfort of the crew, but also damages the Marine environment to different degrees by underwater radiation noise. Therefore, taking a bulk cargo ship as an example, this paper introduces the vibration measurement method of the propulsion shafting of merchant ships, and puts forward Suggestions on the vibration control of the propulsion shafting.

2. Shafting Vibration Classification

The propulsion shaft system of a ship is a typical multi-step multi-support continuous elastomer, including propeller, propeller shaft, intermediate shaft, thrust shaft three parts. The schematic diagram of the propulsion shaft system of the ship is shown in figure 1.

The ship propulsion shafting will vibrate under the influence of many factors in actual operation. For example, uneven transfer torque of the main engine, propeller excitation force, poor alignment of shafting, etc. Vibration of shaft system can be divided into three kinds according to its different forms: torsional vibration, whirling vibration (also known as transverse vibration) and longitudinal vibration. Torsional vibration of shafting is the circumferential alternating motion and the corresponding deformation of diesel engine and propeller under the action of periodic excitation. The whirling vibration of shafting is caused by various factors such as mass imbalance and propeller force. On the one hand, the shafting rotates around its own center line, and on the other hand, the axis is curved and rotates around the original balance axis. The longitudinal vibration of shafting is the periodic displacement and deformation of shafting along the axis caused by the combined forces of various factors.

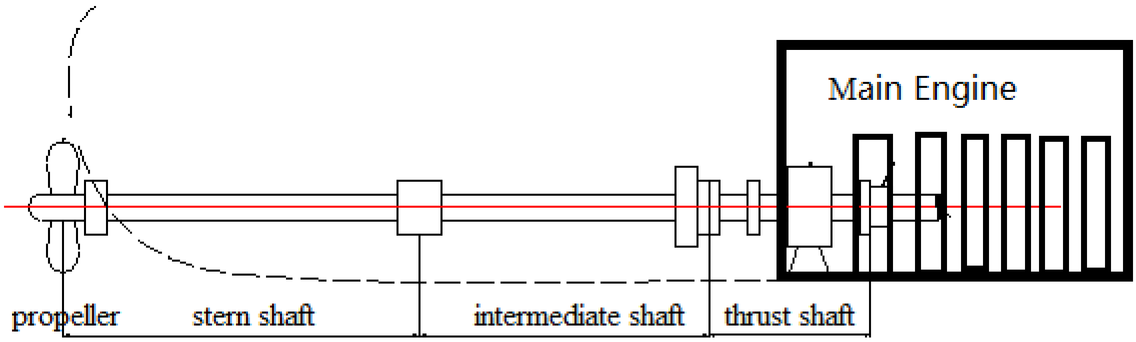

Fig. 1 The schematic diagram of the propulsion shafting

2.1 Torsional vibration

The main factors that lead to torsional vibration of ship propulsion shafting are:

(1) Inhomogeneity of intermittent fuel injection, combustion and output torque of diesel engine;

(2) Error excitation and meshing impact excitation of the gear system;

(3) Improper installation, uneven materials, inaccurate processing and unbalanced quality of ship propulsion shafting components;

(4) The rotation of the propeller in the uneven flow field of the ship generates an uneven excitation to the shaft system.

Serious torsional vibration will lead to: crankshaft (related to diesel engine and shafting arrangement), intermediate shaft fracture; The connecting bolt of elastic coupling is cut off; Elastic element is broken; Local shaft heating and so on.

2.2 Longitudinal vibration

The main factors causing longitudinal vibration of ship propulsion shafting are as follows:

(1) Large alternating longitudinal excitation force (thrust) exerted by propeller operating in non-uniform wake field at the stern;

(2) The gas excitation force in the cylinder of diesel engine (which is related to the arrangement of diesel engine and shaft system) is much smaller than the first two kinds of excitation force for the combined power unit:

(3) Torsional vibration of the shafting system, especially when the torsional vibration frequency is the same or similar to the natural longitudinal vibration frequency, the longitudinal torsional coupling vibration of the shafting system will not be obvious. The coupling of such vibration is mainly completed by the crankshaft and propeller of the diesel engine.

(4) Rotation vibration of shafting can also stimulate longitudinal vibration. This coupling is caused by gearbox and propeller.

The harmfulness of longitudinal vibration of propulsion shafting is mainly manifested in the following aspects:

(1) Excessive bending stress and tensile and compressive stress of crank pin may even cause bending fatigue failure of crankshaft (related to the arrangement of diesel engine and shaft system);

(2) The additional bending load of the transmission gear wheel tooth is too large, which accelerates the tooth surface wear and even damages;

(3) Additional alternating load of thrust bearing;

(4) Secondary excitation force generated by longitudinal vibration of shafting causes vertical vibration of ship girder, local vibration of engine room members and longitudinal vibration of superstructure.

2.3 Whirling vibration

The exciting force of whirling vibration of propulsion shaft system comes from the following aspects:

(1) Centrifugal force of unbalanced rotating mass, shaft system components (including intermediate shaft, tail shaft, propeller) can cause unbalanced centrifugal force of the shaft system due to the eccentric mass of the manufacturing process, especially the wear in the propeller line or a major defect, which can produce a large unbalanced centrifugal force.

(2) The effect on the fluid exciting force on the propeller.

(3) When the flexural stiffness of the rotor shaft is different in each direction, that is, the moment of inertia of the rotor shaft around the two main inertial spindles is not the same, even if the propeller is completely balanced, secondary excitation force with frequency twice the shaft frequency may be generated. However, in the propulsion shaft system, the flexural stiffness of the rotating shaft can be generally regarded as the same in all directions.

(4) Torsional vibration and longitudinal vibration of the shafting system will also cause cyclotron vibration. The coupling sources of these vibrations are gearbox and propeller.

Severe cyclotron vibration will have the following consequences:

(1) Excessive bending stress is generated at the conical large end of the propeller shaft, which will be aggravated by loose nut at the propeller shaft end and vibration and jump of the propeller at the conical part. If the bending fatigue limit of steel decreases sharply due to the corrosion of sea water, the large tapered end of propeller shaft will be cracked and damaged.

(2) The liner bearing is worn at an early stage, leading to corrosion of the shaft bushing, damage of the sealing device and other accidents.

(3) Local vibration of the stern structure.

3. Measurement Method of Ship Shafting Vibration

3.1 Measurement method of torsional vibration

Dual-frequency laser doppler torsional vibration measuring instrument adopts a dual-frequency laser based on zeeman effect and frequency traction effect to generate frequency shift. This method can realize the accurate identification of rotation direction of shafting components, and is especially suitable for the occasions when the rotation system often starts and stops and the rotation direction fluctuates randomly. The dual-frequency laser doppler torsional vibration measurement system is designed with a unique dual-independent laser interferometer. The angular velocity and displacement of the rotating body are measured by laser. The test object is not limited to the cylinder, as long as the rotating motion of the rotating body can be obtained and its translational motion can be restrained, the torsional vibration measurement can be completed. Its working principle diagram is shown in figure 3.

The parallel laser (A, B) with the spacing of d is projected onto A rotation axis. According to the principle shown in the figure above, no matter where the laser irradiates the rotation axis, the sum of doppler frequency shifts of the two laser beams is related to the rotation angular velocity of the object as follows:

$f_d(A)+f_b(B)= 2d\omega/\lambda$

Dual-frequency laser output a beam with two different frequencies of left-handed and right-handed circularly polarized light f_1 and f_2, the frequency difference delta f=| f_1-f_2| value depends on the speed of the rotating magnetic field applied to the laser tube. According to the principle of doppler frequency shift and optical difference beat technology, the frequency after mixing on the photodetector is:

$f_d=|\Delta f\pm(4\pi/\lambda)Nd|$

The dual-frequency laser doppler torsional vibration measurement system which uses magneto-optical modulation method to generate constant frequency difference of laser beam output. The measurement principle is similar to that of reference light measurement method.The angular vibration information can be obtained by measuring the frequency shift of two laser beams.

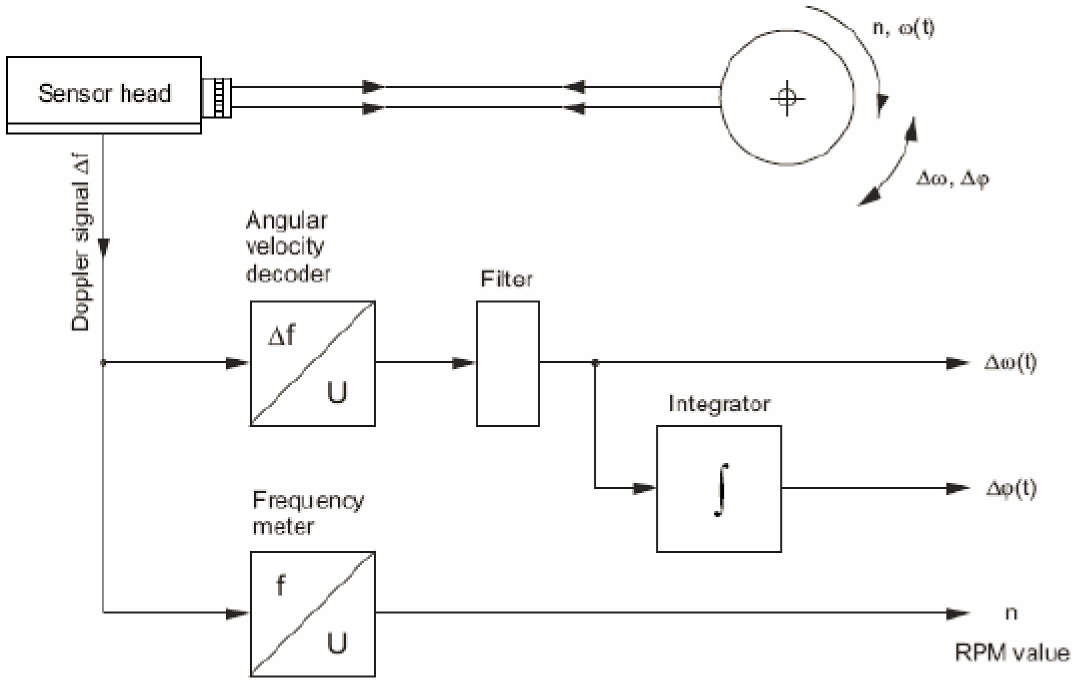

Fig. 3 The working principle of laser torsional vibration measurement system

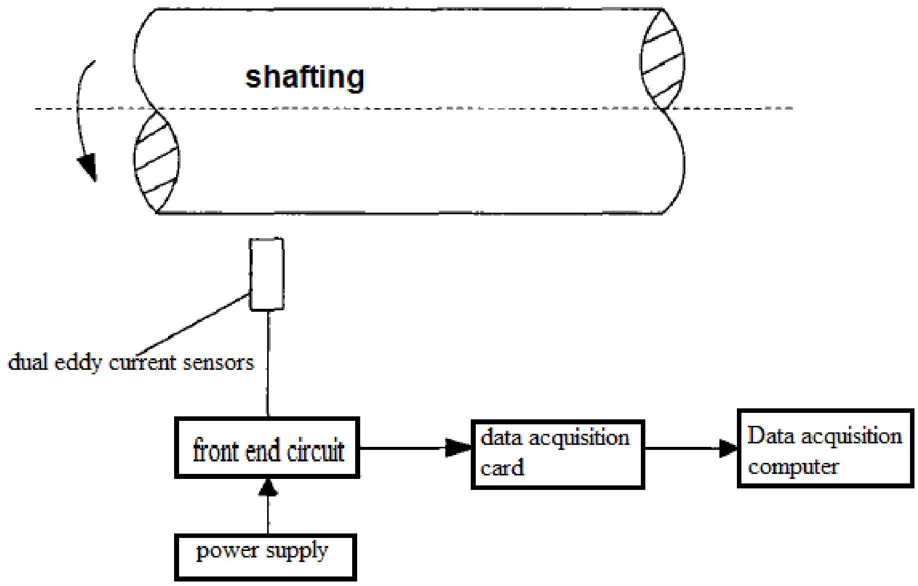

Fig.4 The signal acquisition device for whirling vibration of shafting

3.2 Measurement method of whirling vibration

In this paper, the longitudinal vibration and whirling vibration of shafting are measured by a signal acquisition device for whirling vibration of shafting. The signal acquisition device for whirling vibration of shafting is showed in Fig.4. The signal acquisition device for whirling vibration of shafting is integrated signal acquisition device made up of dual eddy current sensors, front end circuit, data acquisition card, power supply and data acquisition computer. In measuring longitudinal vibration and whirling vibration of shafting with eddy current sensor, the line vibration of shafting surface which changes the coil impedance of eddy current sensor. The sensor signal is converted into analog voltage signal by the preprocessor. The analog signal is converted into digital signal by data acquisition, and the digital signal is processed and analyzed by the data analysis system to obtain the whirling vibration characteristics of the shaft system.

4. Control Method

When the shafting vibration to a certain extent, will lead to the shaft and the host fault, to reduce the power transfer efficiency, and even cause the host body vibration, hull vibration, etc., these will affect the safe operation of ship navigation performance and, therefore, need to study ship propulsion shafting vibration characteristic, according to the propulsion shafting vibration characteristic analysis, this paper puts forward shafting vibration control methods are as follows:

(1) The shaft system is equipped with a highly damped elastic coupling. When the relative amplitude difference between the main and slave ends is large, good vibration reduction effect can be obtained.

(2) Axis alignment. Shafting alignment should meet the requirements of the specification so that each bearing of shafting is under positive load under various working conditions.

(3) Reduce the incentive force. In order to reduce the propeller's exciting force, the tip unloading technology and the large side-slant technology can be used to optimize the propeller design.

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