Analysis And Application Of Marine Friction

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Abstract: This paper expounds the definition and connotation of marine tribology and analyzes the way of friction. Marine tribology involves the problems of internal friction and external friction. The role of marine tribology was proposed, including energy conservation and emissions reduction, prolonging the service life of mechanical system and improving the operation efficiency of the marine, etc.

1. Introduction

The shipping industry is an important part of the integrated transportation system. At present, the total size of China's shipping fleet has reached 160 million DWT, ranking third in the world. Compared with land transport and air transport, water transport has great advantages in terms of economy, safety and environment protection. Ships play an important role in waterway transportation, marine development and nation defense construction. The safe and reliable operation of ships provides guarantee for waterway transportation, marine development and national defense construction. However, climate change and global warming has brought to the world's increasingly strict. The harsh environmental pressure puts higher demands on energy conservation, emission reduction and consumption reduction in the ship and shipping industry. According to statistics, friction consumes more than 1/3 of the world's primary energy, and wear causes about 60% of mechanical material loss. According to the survey of eight fields of metallurgy, energy and chemical industry, railway locomotives, automobiles, aerospace, ships, military equipment and agricultural equipment, the losses caused by friction and wear in China accounted for 4.5% of the national economy in 2006, including ship machinery. About 70% of the failures are related to internal friction and wear. Therefore, the study of ship tribology has caused great concern.

Designing contacts susceptible to fretting is a challenging task due to uncertainties related to friction. For example, coefficient of friction has shown to vary as a function of load cycles and so-called non-Coulomb friction can exist during individual load cycles. Concepts of stable and unstable friction are presented in this manuscript. Based on experiments, no fretting is to be expected if the utilization of friction is kept below unstable friction threshold. If contact is subjected to tangential load above this threshold, reciprocating slippage, fretting, is to be expected even if the contact is initially in stick. Experimental evidence for existence of such threshold is presented in form of friction data, slip data and fretting scars.
1.1 The definition and connotation of ship tribology

Tribology is the science and technology of interacting surfaces for relative motion. Tribology studies cover a wide range of topics, including friction, wear, lubrication, and surface wear reduction engineering. Ship tribology can be divided into two parts: internal friction and external friction: internal friction mainly refers to the key movements of the main engine (cylinder liner – piston ring, crankshaft – connecting rod, bearing – bearing bush, etc.) auxiliary machinery, shafting and deck machinery. Friction of components; external friction mainly refers to the friction between the equipment on the ship's deck and the air, the friction between the hull shell, the propeller, the rudder, etc, and the friction between the ship's crew and the ship's deck.

Ship Tribology aims to serve the energy conservation and emission reduction requirements of ships by studying the friction and wear mechanisms of related equipment involved in the interior and surface of ships. It mainly includes the following four aspects: First, extend the life of tribological components and tribological systems. Second, eliminate or reduce the adverse effects of the tribological components of the ship and the tribological system on the ecological environment throughout its life cycle. Third, tribological issues in the interaction of marine ecosystems with hull surface topography and coatings. Fourth, the use of renewable energy (wind, solar, etc.) in the tribological problems of ship power/auxiliary power mainly involves the friction mechanism of renewable energy equipment in the harsh environment of ship operation.

1.2 Effect of Friction and Wear on Reliability of Marine Diesel Engine

The analysis of the friction and wear of the components of the marine diesel engine is to test the defects in the manufacture and use of the main components of the diesel engine, and to infer the expected life of the components, determine the level of the engineer's operation in the marine diesel engine, and determine its impact on diesel engine reliability and durability.

Failure analysis of diesel engine parts can be used to measure the wear of the main parts when the tank is lifted by the port. For example, measuring the cylinder liner of a diesel engine, the roundness error of the piston and the piston pin, the cylindricity error, the inner diameter increment, measuring the plane clearance of the piston ring, the gap of the lap, measuring the arm distance difference of the crankshaft, etc., depending on the environment in which the part is located. The wear analysis of the contact medium and its own material determines the effective range, location and cause of the part, and determines the repair method according to the processing requirements to restore the original function.

The calculation formula for the wear rate (the maximum amount of wear of the part in the radial direction per unit time):

\[ v = \frac{\Delta_{\text{max}}}{2t} \]

\( \Delta_{\text{max}} \) -- actual maximum wear of the part, μm
\( t \) -- actual working time of parts, h

The formula for calculating the gap rate caused by wear:

\[ v' = (\Delta_{\text{actual measurement}} - \Delta_{\text{install}}) / t \]

\( \Delta_{\text{actual measurement}} \) -- measured gap value
\( \Delta_{\text{install}} \) -- Installation gap value

Because the wear rate is related to the conditions of use of the part, the medium in contact with the part, the manufacturing quality of the part, and the level of the engineer's operation, even the same diesel engine has different wear speeds due to various factors, so wear can be said. Speed is a random quantity, so when calculating the friction and wear speed of a part, it is determined by the statistical characteristic value of the wear rate, which is determined by the average variance and the average wear rate.

The formula for calculating the residual working life of the part:

\[ t = (\Delta_{\text{max}} - \delta_{\text{max}}) / v \]

\( \Delta_{\text{max}} \) -- allowable ultimate wear value, μm
Statistical analysis of the measurement results of the main components of the diesel engine, the relevant values of their wear speed are obtained, the actual service life of the parts is determined, and the actual working life is compared with the working life of the specification, and the key to the actual effect of the parts is obtained. Factors and develop various preventive measures to improve the working life of components and improve the reliability of diesel engines.

Statistical average of wear rate:

$$v_{av} = \frac{\sum_{i=1}^{N} v_i}{N_i}$$  \hspace{1cm} (4)

Statistical average of variance:

$$\sigma_{av} = \sqrt{\frac{1}{N}[\sum_{i=1}^{N} V_i^2 N_i V_{av}^2]}$$  \hspace{1cm} (5)

N--determine the amount of actual wear rate

The wear of the components directly affects the performance and reliability of the diesel engine, especially the wear of important fittings such as piston rings, cylinder liners, crankshafts and bearings. We evaluate the durability and quality of the diesel engine. The statistical average of the wear rate and the statistical average of the variance can be used to determine the distribution of the wear rate of the component, and then calculate the actual use of the diesel engine based on the actual service life of the component. The reliability of work.

1.3 Friction of the transmission element

The ship must inevitably play the role of the propeller during the driving process. When the main engine of the ship generates power, the propeller is driven by the transmission element, and it is difficult to avoid the friction loss in this process. The traditional ship transmission component material is the under the keel bearing, which is thrown away from the friction damage, and will also partially dissolve under the action of the lubricant, which is very serious to the passing river.

According to relevant research, the shape of the water tank has a great influence on the friction factor of the bearing. When the water tank is narrow, the bearing friction is increased due to the increase of the bearing capacity. In addition, some scholars have studied that the arrangement of the water tank can also affect the friction factor, and the friction factor is minimized when placed directly below the tail shaft.

1.4 Contact resistance analysis method

The electric resistance method is to measure the contact voltage drop of the friction pair by utilizing the difference between the conductivity of the metal and the conductivity of the lubricating oil, and to calculate the oil film thickness between the surfaces of the friction pair by using the relationship between the thickness of the oil film and the resistivity of the oil film. When the cylinder liner is in direct contact with the piston ring, the resistance is inevitably small when the two metals are in direct contact, but as the lubricating oil enters, the expansion of the oil film causes the cylinder liner to be separated from the piston ring, resulting in an increase in contact resistance; When a portion of the microprotrusions pierce the oil film, the two metals re-contact, causing a decrease in electrical resistance. Since the electrical resistivity of the metal and the oil film is very different, the change of the state of the lubricating oil film in the test causes a large change in the contact resistance, and the change of the oil film can be qualitatively analyzed from the change of the contact resistance, thereby accurately reflecting the cylinder through the contact resistance. Set - the lubrication state between the piston rings.

1.5 Stable and unstable friction in fretting contacts

Fretting stands for reciprocating surface sliding and wear and fatigue damage associated with it. Commonly in fretting, the slip amplitude is low, in range of few micrometers; however, it can be tens or
even hundreds of micrometers. Fretting wear is characterized by occurrence of finely textured wear debris, which tends to entrap inside the contact. Fretting fatigue is considered especially harmful due to potentially catastrophic component failures and by the fact that fretting fatigue failure initiates inside the contact and thus is difficult to be observed. Fretting induced surface degradation accelerates fatigue crack initiation, making evaluation of fretting fatigue loads difficult. A more comprehensive description of fretting and contacts is available in these Refs.

Engine designer wants to squish out most of the available engine performance leading to high utilization of material strength. This narrows acceptable margin of error, both in the loads and the material strength sides. Design against fatigue is made difficult by the presence of highly loaded contacts due to additional uncertainties related to fretting induced friction and surface degradation. It is well known that fretting can impair components fatigue endurance; hence, it may be desirable to avoid fretting altogether. Before this can be achieved, the designer needs to know how much of the available friction can be safely utilized, though this is made difficult by the fact that non-idealities.

Concentrated contacts or incomplete contacts, such as the Hertzian point contact, are highly usable in fretting research, but are somewhat limited in achievable contact size. Regardless, it has been demonstrated that considerable size effects exists both in fretting fatigue and in fretting wear, which rises concern to the engineer’s mind when implementing fretting research findings to machine design because component interfaces tend to be orders of magnitude larger than the fretting contacts used in literature.

This study aims to find out how much of the available friction can be utilized before friction starts to show unstable behavior, observed previously in gross sliding fretting experiments, and when fretting damage starts to occur. Fretting experiments are running in stick and partial slip conditions. Hence, only a fraction of the available friction was utilized in these experiments.

1.6 Theoretical model of friction nanogenerator
The displacement current theory is the output characteristic of the nano-generator from the internal current (the inside of the material), and the capacitance model of the nano-generator is the dynamic transportation process of the circuit when the load is derived from the external circuit according to Ohm's law. For an external circuit, when the electron flows back and forth between the two electrode plates, the nanogenerator acts like a capacitor. The output voltage drives the flow of electrons in the external circuit. The basic working principle of a friction nanogenerator is the coupling of contact and electrostatic induction. Contact electrification provides a static polarization charge, while electrostatic induction is the primary mechanism for converting mechanical energy into electrical energy.

2. Conclusion
The study of ship tribology has a unique role in energy conservation, emission reduction, noise reduction and life expectancy. Active use of ship tribology knowledge in ship design, manufacturing, operation and management can achieve the direct goal of energy saving and consumption, and further contribute to the realization of green, healthy, energy-saving and environmentally friendly shipbuilding powers and shipping powers.

References
[1] Maziran, (2017) Investigation of Self-active Sensor Based on Triboelectric Nanogenerator for Ship Draught Detecting. Master dissertation: 20-26.
[2] Yan xiping, (2015) Review and prospect of marine tribology. Nature magazine: 157-164.
[3] Guo yunhua, (2016) UAV Path Planning Based on Improved Quantum-behaved Particle Swarm Optimization Algorithm. Ship &ocean engineering: 91-102.
[4] Yu Junhonn, (2018) Influence of pressure distribution and friction on determining mechanical properties in the Brazilian test: Theory and experiment. Solids and Structures: 1-12.
[5] Jouko Hintikka, (2018) Stable and unstable friction in fretting contacts. Tribology International: 73-82.
[6] PEI S, MA S, XU H, (2011) A multiscale method of modeling surface texture in hydrodynamic regime [J]. Tribology International, 44: 1810-1818.