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Test method of cavitation erosion for marine coatings with low hardness

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ABSTRACT

Rudders of large container ships are easily affected by cavitation, which is well known to be induced by significant axial flows behind a propeller and discontinuities in the rudder. Among several methods to prevent or reduce the cavitation erosion occurred in the rudder, painting is gaining a lot of attention because it can be employed easily and cheaply. To conduct erosion tests properly, the simulation of heavily erosive cavitation is necessary. This can be generated using an inclined propeller dynamometer in the medium-size cavitation tunnel of MOERI (Maritime & Ocean Engineering Research Institute). The inclined shaft of the propeller creates strong cavitation, which occurs around the root of the propeller blade. This cavitation creates impacts through the collapsing process that are very severe, and are useful for realistic and efficient cavitation erosion tests. In the present study, the newly developed cavitation erosion test method is successfully employed to evaluate marine coatings that is mainly composed of epoxy elastomer or silicone polymer material. Silicone polymer-type paint B was found to have three times larger endurance than epoxy elastomer-type paint A.

1. Introduction

The surfaces of marine ships and offshore plants are easily exposed to corrosive environments by sea water or fouling by algae or barnacles. To prevent these things, heavy duty and anti-fouling coating systems are applied to marine structures. In the case of marine propellers or rudders, the high-flow velocity and low pressure distribution around them have frequently caused strong cavitations. In particular, it has been reported that erosion by strong cavitation on the marine rudders results in dangerous damages to the rudders' surfaces. Modifications to the rudder gap entrance profiles (Kim et al., 2006; Paik et al., 2007) or leading edge shape have been developed by shipbuilding companies, ship owners, and related researchers to avoid rudder cavitation problems; however, complete solutions have not yet been provided. One effective solution is increasing the cavitation resistance in the rudder surface using a special surface treatment, which has been created according to the discretion of shipbuilding companies or the requirements of ship owners. The specific surface treatment method involves the application of organic coatings that exhibit high cavitation resistance. To examine the performance of cavitation resistance in marine coatings, appropriate erosion test methods should be established.

Vibratory rigs have frequently been used for cavitation erosion tests. The standard erosion test method of ASTM G-32 ⟨http://www.astm.org/Standards/G-32.htm⟩ has generally been used. The vibratory rig shown in Fig. 1(a) had a high frequency oscillator (~20 kHz) with very small amplitude (30–40 μm), and simulated cavitation erosion effects using ultrasonic waves. Kim (1999) and Kim et al. (2003) investigated the cavitation erosion behaviors and damage characteristics of materials such as cast iron, brass, STS 316, and DuraTough using the ASTM G-32 method. Hattori and Nakao (2002) also studied the cavitation erosion mechanism in annealed and heat-treated steel using the ASTM G-32 method. This method is effective in tests for the high hardness material such as metals or ceramics; however, it is known to show unreliable test results for low hardness materials such as polymers. A modified ASTM-G-32 method has been suggested to conduct reliable cavitation erosion tests for low hardness materials such as polymer. The sample material in the modified ASTM G-32 method is positioned at a small distance from the oscillator in the vibratory rig, and vibration and liquid are applied to the oscillator to simulate cavitation, as shown in Fig. 1(b). Although the two methods certainly showed different test results for the silicone polymer, the epoxy elastomer material showed similar test results, as shown in Table 1, and still did not give sufficient reliability in the cavitation erosion tests. In addition, these two methods have been criticized because the cavitation simulated by ultrasonic waves is different from the real cavitation occurring in a full-scale situation.

Besides vibratory rigs, several methods such as cavitating jets (Soyama et al., 2001), liquid jets, rotation disks, water tunnels

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(Sakamoto et al., 2000), etc. have been used for cavitation erosion tests. These generally require 5–20 h of operation time for the erosion test. The cavitation impact simulated by the conventional methods mentioned is not considered to be enough; much time/cost is incurred for usable erosion tests. Above all, since cavitation collapsing may not occur right on the specimen's surface, or the magnitude of collapsing pressure may be too small to make erosion pits, a lot of time is required to simulate erosion damage.

A new erosion test method must therefore be developed that can estimate the erosion resistance of special paints with low hardness against strong cavitation collapse within a relatively short duration time of less than 3 h. The developed cavitation erosion test method has to show good effectiveness in the estimation of erosion resistance. Furthermore, the characteristics of the cavitation in the model scale should be similar to those occurring on a full-scale.

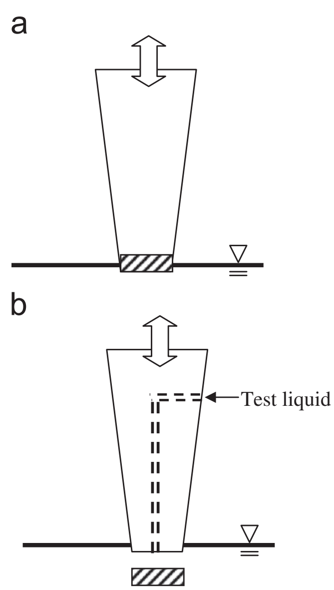

Fig. 1. Sketch of ASTM G-32 methods: (a) ASTM G-32 method and (b) modified ASTM G-32 method.

Table 1
Comparison of cumulative erosion depths after 1 h erosion test.

Material type	Test type	Erosion depth (μm)
Silicone	G-32	650
	Modified G-32	13
Elastomer	G-32	10
	Modified G-32	12

2. Experimental apparatus and method

In this study, an inclined propeller dynamometer and model propellers were used to solve the problems stated above. The newly developed test method formed very erosive cavitation collapse on the surface of the marine coating, which was painted

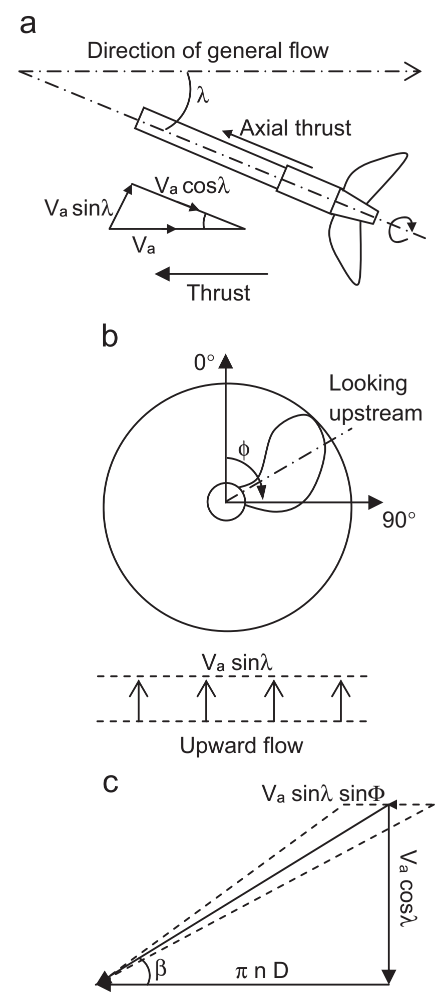

Fig. 3. Velocity vector on propeller blade with inclined shaft: (a) side view, (b) plan view, and (c) vector configuration.

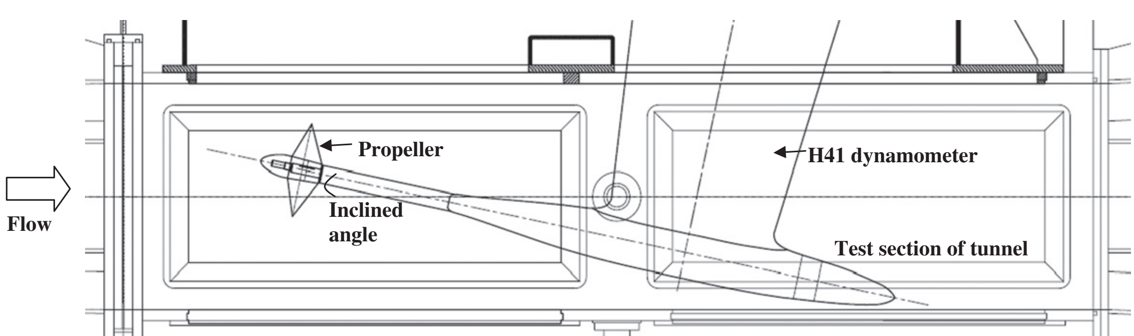

Fig. 2. Medium-size cavitation tunnel and the inclined propeller dynamometer.