Biofouling Monitoring Experiments of Underwater Concrete Samples for Offshore Platform Cleaning Robot Development

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Abstract

As the Japanese government decided to boost the carbon neutral power source development, offshore wind farm projects are emerging in Japan and hundreds of platforms will be constructed in the near future. Some of these platforms are possible to be floating structures and made of concrete-like material whose biofouling should be limited from the viewpoint of drag force reduction. An autonomous cleaning robot is one of possible solutions to minimize the effect of biofouling. To develop the cleaning device, we started field experiments to study biofouling process. In this paper, we introduce some results of biofouling monitoring experiments using several different concrete-like samples at sea.

Keywords: Offshore Power Plant, Biofouling, Unmanned Maintenance, Concrete Sea Exposure Experiment.

1. Introduction

Offshore wind power projects are becoming more active in the waters near Japan. There are fixed and floating options for offshore platform types. In the case of a floating platform, biofouling may cause an increase in fluid resistance and weight in the floating part, and it is considered desirable to remove it. On a fixed platform, the impacts described above are expected to be relatively small, but from a structural maintenance standpoint, it may be desired to remove marine biofouling. Subsea structures such as subsea mining is also desired to be cleaned in the deep water to maintain its mechanical functions[1]. It is expected that waves will be high in the waters near Japan that are suitable for offshore wind power generation. In such areas, the removal work performed by divers is not only dangerous, but also limits the number of days that can be worked. Therefore, it is desirable to develop a robot that can automatically clean underwater structures such as columns and foundations.

The columns of the structure are currently made of steel or concrete. The steel columns are coated to reduce biofouling. In the development of a cleaning robot, it is necessary to develop a cleaning device so that this coating will not be damaged. On the other hand, in the concrete column, the concrete is exposed to seawater. It has been reported that in conventional harbor structures, biofouling developed to cover the surface of concrete has a positive effect on the life of concrete because it plays a role in preventing seawater components from penetrating into concrete[2].

This research started to investigate a method for removing biofouling in concrete structures, unlike the conventional research that actively promotes biofouling. We envision cases where it is desirable to reduce fluid resistance, such as floating platforms and cooling water pipes in power plants. From the standpoint of eliminating biofouling, the authors think that it is necessary to consider the following three points.

(i) Development of new materials and surface treatment methods that prevent the penetration of seawater components
(ii) Understanding the process of development of biofouling on concrete surfaces
(iii) Removal method by cleaning robot

In order to proceed with the study on these three points, the authors started an experiment to observe the state of biofouling using different types of concrete test samples[3]. In this paper, we will introduce the method of the experiment on our pier, some experimental results, and some aspects in developing the cleaning robot that we are studying at this stage. The experiment is being conducted at the pier of School of Marine Science and Technology, Tokai University in Shimizu port.

2. Some Aspects to be Considered in Developing the Cleaning Robot

The robot is put into the sea from a support ship or a platform. The robot's power is either built-in battery of the required capacity or supplied externally through an umbilical cable. The housing of the robot can be deformed according to the curve of the column to be cleaned, and the robot housing is designed so that cleaning tools such as brushes can always stick to the column. Regarding cleaning equipment consideration, we will proceed its design with the examination while clarifying how the species and biomass change over time through ocean exposure experiments. As concrete is a brittle material, and at the same time, attached organisms such as barnacles can chemically integrate with the concrete material, so forcibly peeling off barnacles can damage the concrete surface. Therefore, it is necessary for us to devise a method different from the cleaning equipment that is being studied for steel materials such as ship-hull cleaning robots.

Table 1 Basic System Configuration of the Robot

Basic System Configuration
Thrusters and Actuators
Cleaning Device
Underwater Camera with Lights
Underwater Position Detection System
Inertia Measurement Unit
Communication Interface
Removed Debris Recovery System
Control System
Power Source

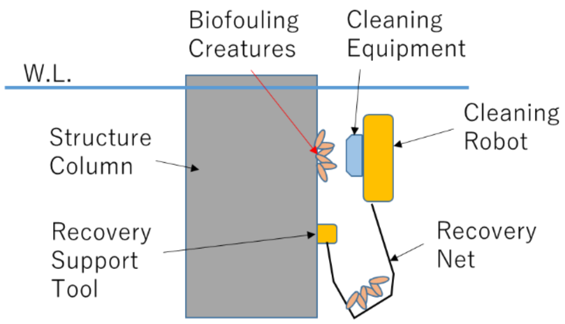

Fig. 1. Conceptual Schematic View of the Cleaning Robot.

In order to reduce the impact on the marine environment, the removed attached organisms must be recovered by robots rather than released into the sea. The mechanism of the cleaning equipment and the recovery device needs to be designed to function as one system, and in order to optimize these, it is necessary to know the formation process of biofouling of concrete material through actual sea experiments.

Table 1 shows the contents of the basic system configuration of the cleaning robot currently planned. Figure 1 shows a schematic diagram of the concept of robot operation. In order to automatically control the robot, it must be possible to detect the underwater position, speed, and attitude angles of the robot. A communication system with the land base is required to capture the cleaning status with an underwater camera and monitor it at the land base. The robot's movement and trajectory tracking control are performed by thrusters, and actuators that operate cleaning equipment are also required. The cleaning operation is performed automatically while following a given trajectory.

3. Biofouling Experiment at Pier

The sea exposure experiment is being conducted at the pier of the School of Marine Science and Technology, Tokai University. As shown in Fig. 2, different types of concrete test pieces are hung. Since it is considered that many attached organisms such as barnacles develop near the water surface, the case near the water surface as shown in Zone B in the figure and the case near the seabed as shown in Zone C were set for comparison. Figure 3 shows how the test pieces are arranged in the pier in Zone B. The height of a piece is adjusted around the mean sea level and it appears above the sea surface when the tide is low, on the other hand, it submerges beneath the sea surface when the tide is high. The pieces in Zone C are always fully submerged near the seabed.

A ring-shaped pile was embedded during concrete molding to hang the test piece. The size of the test piece is about 0.1 m in length, about 0.1 m in width, about 0.2 m in height, and weighs about 49 N. The weight of each test piece was precisely measured as shown in Fig.6. By accurately measuring the weight over time, the amount of attached biomass is estimated.

4. Some Experimental Results

The test piece was first installed on August 26, 2021, but since the metal fittings that hang the test piece corroded and fell, the test piece was newly installed on September 21, 2021, except for the two test pieces. Figure 4 shows a test piece appearance in Zone B before the installation. Figure 5 shows the development of biofouling on the test piece on October 20, 2021, about one month later. Figure 6 shows further development of biofouling of the test piece on November 15, 2021, about three months later.

As shown from Fig. 4 to Fig. 6, barnacles mainly grew on the concrete surface in Zone B. After 1 month, the concrete surface was visible in some places, but after 2 months, the entire surface of the concrete test piece was thickly covered. Figure 7 shows the mass increase rate of the test piece. In the most increased case, a 10% (about 5N) increase was seen in about 80 days. That is, it was suggested that it leads to a non-negligible weight increase in floating offshore structures.

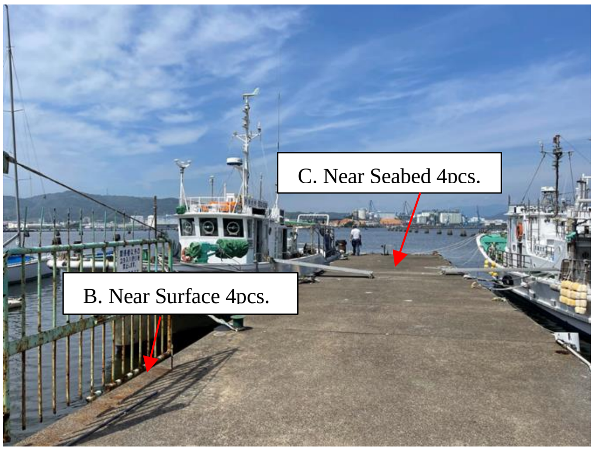

Fig. 2. Zoning of Test Pieces Arrangement at Pier.

Fig. 3. Near Surface Condition in Zone B.

Fig. 4. A Test Piece Appearance before Installation.

5. Conclusion

In this article, we introduced the concept of a robot that automatically removes marine-attached organisms, assuming a concrete column of a floating offshore structure. In order to find effective solution of cleaning

Fig.5 A Test Piece Appearance after One Month.

Fig.6 A Test Piece Appearance after Three Months.

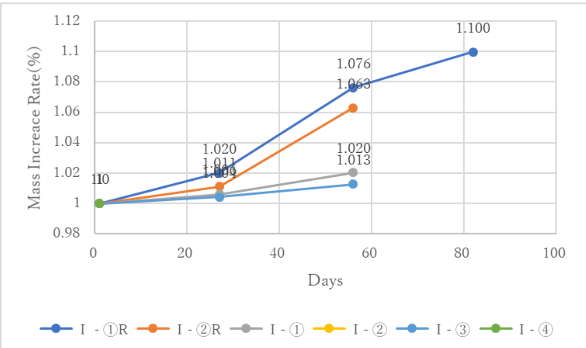

Fig.7 Mass Increase Rate of Test Pieces.

equipment of the robot, we started sea exposure experiment of concrete test pieces. The experimental setups and some early stage results were presented. Although further investigation is needed, the result implies biofouling is possible to influence the structure dynamics and its removal might be meaningful.

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