5. Propulsion Systems

5.1 General

According to the Nihon Kaiji Kyokai (ClassNK), a total of 397 vessels were newly built in FY 2016 in Japan. The number, which excluded barges, pleasure boats and yachts, was down by 57 from FY 2015. It can translate into around 2,840 MW, which was a 390 MW reduction compared to the previous year. The shaft number used in these newly built vessels was 450 in FY 2016, down by 79. Details of the statistics about the production of propulsion systems in Japan in FY 2016 are as follows.

- Single-engine single-shaft systems = 344 ships
- Two-engine single-shaft systems = 0
- Two-engine two-shaft systems = 52 ships
- Single engine two-shaft systems = 1 ship
- Four-engine four-shaft systems = 0
- Ships with oil lubricated propeller shafts = 306: ships with seawater lubricated ones = 91
- Propeller shaft classification: 1C = 136 shafts (all of them were single-engine single-shaft ships); 1A (partly covered in rubber) = 1 shaft (one-engine one-shaft ship); 1A (partly covered in resin) = 4 shafts (four ships with one engine and one shaft)
- Ships with fixed pitch propellers = 388: ships with controllable pitch propellers = 9
- Nickel-aluminum bronze propellers = 91.2 percent
- Keyless propellers = 84.1 percent
- Highly skewed propellers = 18.1 percent
- Steerable propulsion systems = 3 ships
- Contra-rotating propulsion systems = one ship

While marine energy saving efforts are becoming more intense recently, backed by the adoption of the Energy Efficiency Design Index (EEDI) and other regulations, various technological projects are underway to conserve energy. This section highlights the high response, electric control CPP (controllable pitch propeller), which is a new energy saving element incorporating CPP technology.

5.2 High Response, Electric Control CPP

5.2.1 Introduction

The controllable pitch propeller (CPP) has been installed on domestic vessels to ensure maneuverability and protect main engines from being overloaded. The national university corporation Osaka University, the national research and development corporation National Maritime Research Institute, Furuno Electric Co., Ltd. and Kamome Propeller Co., Ltd. rediscovered the CPP as an energy saving device, and they are jointly developing an energy saving marine operation system by controlling rotational speed of shafts and the blade pitch angle of the CPP at the same time1)2) with support from the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) and the Nippon Kaiji Kyokai (Class NK). MLIT designates this endeavor as one of its projects to support technological development of the marine environment for the next generation.

This new system will measure ocean waves encountered by ships while sailing using wave radar measurement systems (Fig.1). Based on estimates of inflow velocity on the propeller blade that can fluctuate momentarily, the system will control shaft speed and the blade pitch angle of the CPP
simultaneously with high responsiveness achieved through feed-forward control, and enable energy-saving navigation with minimum fuel energy consumption. As shaft speed of electric motors (electric propulsion vessels) is easier to control than that of diesel engines, the system is expected to rely on these motors to manage shaft speed with pitch angle controlled by the high response, electric control CPP. Kamome Propeller Co., Ltd. has already developed a new prototype CPP and completed operational checks of the prototype.

Fig.1 Wave radar image

5.2.2 Prototype

The previous study, called ‘research on algorithm for control of blade pitch angle to optimize fuel consumption through tests on real ships’⁴, found that when ships advance against approaching waves, they encounter them more frequently, making existing speed to change the blade pitch angle of the CPP and the current level of CPP’s responsiveness unable to catch up with calculated values. This means that limits are imposed on the degree to which the pitch angle is controlled. For this reason, Kamome Propeller Co., Ltd. planned the creation of a new CPP and produced a prototype. The Fig.2 shows what it looks like.

Fig.2 Prototype

Existing controllable pitch propeller systems are driven by electric power and oil pressure, using a mechanism containing the two different systems. The pitch angle is operated by controlling the volume of hydraulic oil supplied to a blade angle control device, and this device is driven by a hydraulic power source driven by a separate electric motor. This complex process makes it difficult for existing CPP
systems to obtain fast response, and imposes a limit to the accuracy of the blade pitch angle. In consideration of this, the prototype CPP adopts electric motor driven systems to improve speed to change the blade pitch angle and its responsiveness. This allows blade angle to be directly operated by controlling the unit of an electric servo motor with an actuator that is installed inside a propeller hub.

The newly developed CPP is called ‘DDS-CPP’, which includes key features of the product, ‘Direct Drive’ and ‘Servo’.

The Fig.3 and Fig.4 show a DDS-CPP propeller hub and a DDS-CPP power board respectively. The unit of an electric servo motor with an actuator is installed in the cylinder part of the propeller hub, and receives power supply from the power board.

The previous study suggested that the speed to change the blade pitch angle of the CPP should be at least 3 degrees per second to meet a requirement for energy-saving navigation. Consequently, the prototype incorporates the unit of an electric servo motor and an actuator that can adjust the speed to change blade angle to clear this benchmark. The direct operation of pitch angle by controlling the unit inside the propeller hub has achieved improved responsiveness compared to the existing models.
Furthermore, since pitch angle is measured by controlling the position of an actuator, the accuracy of the blade pitch angle has improved drastically. In the prototype, the stroke margin for an actuator is within 0.1mm. This equates to about 0.05 degrees for pitch angle.

In the CCP systems driven by electric power and oil pressure, the oil distribution box that provides hydraulic oil to the blade angle control device is usually placed on the oil supply shaft. In contrast, the DDS-CPP equips a power supply apparatus with slip rings (Fig.5) providing electricity to the unit.

![Fig.5 Power supply apparatus](image)

Major characteristics of the DDS-CPP, its high speed to change the blade pitch angle, responsiveness and accuracy to control the blade pitch angle, should go beyond the scope of research and development introduced in this section. It is hoped that they will be fully utilized in the future as technological elements to develop highly advanced energy saving ships.

References
2) Fukazawa, Odagiri, Suzuki, Suzuki, Umeda, Makino, Hirano, Tanizawa, Hirata, Sekiguchi, B. Oleksiy, Kitagawa, Shiraishi, Development of Marine Energy Saving Technology Taking Advantage of the Simultaneous Control of Rotational Speed of Shafts and the Blade Pitch Angle of the CPP, Japan Institute of Marine Engineering publication 52-2 (2017) 20-23

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