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Parametric study of propeller boss cap fins for container ships

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ABSTRACT: *The global price of oil, which is both finite and limited in quantity, has been rising steadily because of the increasing requirements for energy in both developing and developed countries. Furthermore, regulations have been strengthened across all industries to address global warming. Many studies of hull resistance, propulsion and operation of ships have been performed to reduce fuel consumption and emissions. This study examined the design parameters of the propeller boss cap fin (PBCF) and hub cap for 6,000TEU container ships to improve the propulsion efficiency. The design parameters of PBCF have been selected based on the geometrical shape. Computational fluid dynamics (CFD) analysis with a propeller open water (POW) test was performed to check the validity of CFD analysis. The design of experiment (DOE) case was selected as a full factorial design, and the experiment was analyzed by POW and CFD analysis. Analysis of variance (ANOVA) was performed to determine the correlation among design parameters. Four design alternatives of PBCF were selected from the DOE. The shape of a propeller hub cap was selected as a divergent shape, and the divergent angle was determined by the DOE. Four design alternatives of PBCF were attached to the divergent hub cap, and the POW was estimated by CFD. As a result, the divergent hub cap with PBCF has a negative effect on the POW, which is induced by an increase in torque coefficient. A POW test and cavitation test were performed with a divergent hub cap with PBCF to verify the CFD result. The POW test result showed that the open water efficiency was increased approximately 2% with a divergent hub cap compared to a normal cap. The POW test result was similar to the CFD result, and the divergent hub cap with the PBCF models showed lower open water efficiency. This was attributed to an increase in the torque coefficient just like the CFD results. A cavitation test was performed using the 2 models selected. The test result showed that the hub vortex is increased downstream of the propeller.*

KEY WORDS: Energy saving device; Propeller boss cap fin (PBCF); Hub vortex; Hub cap; Container ship.

INTRODUCTION

The global quantity of commercial traffic including container traffic in marine logistics has decreased significantly due to the global recession. The global economy began to enter recession after the Sub-Prime Mortgage Crisis in the United States. According to Bloomberg, the Baltic dry index (BDI) decreased sharply by 7343 points to 867 points in 2008. The impact of this decrease on the shipping and shipbuilding industries is expected to be significant over the next few years. The global oil price has increased gradually since 2002. In 2008, the oil price reached US $143.95 per barrel. The demand for energy in developing

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and developed countries is increasing steadily but the fossil fuel energy resources are finite and limited in quantity. As a result, the price of oil is expected to increase continually in the future. The price of Bunker C fuel also increased significantly. The high price of Bunker C fuel is the greatest burden to shipping companies with the low freight fare market, because it accounted for a large portion of the operating costs. Therefore, energy-saving measures have attracted considerable attention and shipbuilding industries have attempted to develop competitive hull forms and energy saving devices.

Furthermore, as global warming proceeds, many countries have been strengthening their domestic and international regulations across all industries. The regulations to limit the exhaust gases from ships and the discharge of ballast water, which is led by International Maritime Organization (IMO) and developed countries, have been strengthened. Therefore, shipping companies are faced with the several environmental requirements to effectively manage environmental pollution.

Significant global consultation and institutionalized efforts between the related bodies, including international authorities, classification societies, ship builders, shipping companies, and local government, have been made to satisfy the environmental pollution regulations. As a result, the IMO enacted the Energy Efficiency Design Index (EEDI), which is scheduled to take effect on January 2014 for carbon dioxide reduction in ship operation and building. Because of international demand, studies on how to reduce fuel consumption and greenhouse gas emissions have been conducted actively in the areas of hull resistance, propulsion and operation. Research into energy saving devices has also been conducted. The following gives a brief review of the leading studies in energy saving devices.

A comparative study of experiments and computational simulations of the condensed loaded tip (CLT) propeller (Beretta et al., 2012) and a comparative study of the biased asymmetric pre-swirl stator (PSS) propulsion system (Kang et al., 2004) have been carried out. The effects of the PSS (Celik and Guner, 2007), vane wheel (Chen et al., 1989), and duct propeller (Inukai et al., 2007) on the propeller efficiency were identified. The mechanical design of a contra-rotating propeller (CRP) assembly for a small underwater remotely operated vehicle (ROV) was reported (Thaddeus, 2006). A number of other devices have also been studied.

Among these energy saving devices, the PBCF is the most efficient device. Installation is simple and inexpensive due to the simplicity of the PBCF. As shown in Fig. 1, the PBCF consists of small fins attached to the boss cap behind the propeller. The PBCF rectifies the down flow from the blade trailing edge and eliminates the powerful hub vortex, so that the PBCF recovers the energy loss from the hub vortex and improves the propeller efficiency.

Fig. 1 Shape of propeller boss cap fin.

Ouchi et al. (1988; 1989) modeled the effects of the PBCF on the propeller efficiency and confirmed the results experimentally. Although the uncertainty in a full scale analysis is generally larger, the energy-saving effects of PBCF are larger on a full scale than in model tests based on full scale analyses of 16 different vessels (Nojiri et al., 2011). Hansen et al. (2011) performed sea trials with a model and a full scale evaluation of a PBCF fitted to an Aframax ship, and reported a 3.5 and 4% decrease in shaft horsepower under ballast and load conditions. Kawamura et al. (2012) investigated the combined effects of the Reynolds number and wake, and found that an increased Reynolds number and the presence of a hull wake positively affected the PBCF under full scale conditions.

This study examined the design parameters of the PBCF and hub cap for 6,000*TEU* container ship in the manner of propulsion efficiency. The first part reports the results of CFD analysis with a POW test to ensure the validity of the CFD analysis.