

## Development of an Experimental Methodology for Self-Propulsion Test With a Marine Diesel Engine Simulator

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This paper introduces the development of a marine diesel engine simulator and proposes a new experimental methodology for self-propulsion test in waves. A marine diesel engine simulator is developed for self-propulsion test of a model ship. This is composed of a servomotor, speed controller, dynamometer and PC. The marine diesel engine simulation program is installed on the PC. Based on mathematical modeling of the engine, this program simulates fuel supply control by governor, torque generation by combustion and shafting system rotation. Inputs are rotating speed and propeller torque measured by dynamometer, and output is target speed to the speed controller of the servomotor. This is a real-time control system of propeller rotating speed, which reflects the characteristics of a marine diesel engine. Using this system, the authors conducted a self-propulsion test of a model ship in waves and checked system operation capabilities. We can measure not only ship motion responses but also the realistic dynamic responses of a ship propulsion system in waves such as propeller load and rotating speed fluctuation, fuel supply rate, etc.

### INTRODUCTION

Performance of ships is customarily evaluated in the calm sea even though ships are operated in wind and waves. This is due to the absence of practical technology to guarantee ship performance in actual sea conditions. Accordingly, contractees have no choice but to accept the result of sea trials based on this business practice. This situation has hardly improved in decades. However, to meet the recent requirements of energy saving and CO<sub>2</sub> emission reduction, it is recommended to develop new technologies to estimate real performance of ships in actual sea conditions. Needless to say, ship performance in calm sea conditions, or “calm sea performance”, is the base for that in actual sea conditions, or “actual sea performance.”

The following procedure is commonly used to estimate calm sea performance in the design stage:

1. Towing tank test to measure hull resistance coefficient in calm water.
  2. Propeller open test to measure its torque and thrust coefficients and efficiency.
  3. Self-propulsion test to measure self-propulsion factors such as wake coefficient ( $1-w$ ) and thrust reduction coefficient ( $1-t$ ).
- From these results, the required engine power is estimated to achieve her service speed in the calm sea. The nominal speed loss in wind and waves can be estimated by following additional tests:
4. Towing tank test to measure added wave resistance in waves.
  5. Wind tunnel test to measure wind resistance. This test is optional and empirical regression formulae are usually substituted for the wind tunnel test.

The results of the model test conducted at the model Reynolds number are corrected to those at the ship Reynolds number. These experimental procedures are widely used throughout the world.

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However, we must not forget one important factor: the engine. Even though the engine is the power source of ship propulsion, only its output and mean rotating speed in steady operation is considered. In actual sea conditions, due to the orbital motion of water particles caused by incident waves and 6 DOF ship motions, inflow velocity to the propeller fluctuates. That causes propeller torque and rotating speed fluctuation. This fluctuation cannot be evaluated without the engine. The propeller and engine compose a strongly coupled system and response characteristics of the engine play an important role. As the engine is the part consuming fuel, we cannot ignore its response in waves when we need to evaluate fuel consumption in the actual sea. Considering the engine characteristics in waves opens up a new way to design, optimization and ideal tuning of ship hull, propeller, engine, governor, turbo charger, etc.

Not many studies have been conducted on ship performance in waves considering main engine response. Tasaki (1957) studied the characteristics of the driving machine in self-propulsion test in waves. He introduced the transfer function of driving motor and simulated its responses with the propeller and the surge motion of ship. Ikegami and Imaizumi (1978) studied nominal speed loss of ship in waves by model experiment. They developed an engine-simulated self-propulsion apparatus to conduct the model test. The apparatus has three modes: rotation number control, torque control and power control. In those days, microcomputers were not available and realistic simulation of the main engine was very difficult. Naito et al. (1979) studied an estimation method of ship speed reduction in waves. In their study, main engine characteristics were considered by introducing two linear coefficients  $E_{QN}$  and  $E_{QA}$  representing the derivatives of engine torque with respect to rotation number and fuel input. Kim et al. (1985) studied the propulsive performance of low speed ship in seaway. The linear coefficients  $E_{QN}$  and  $E_{QA}$  were also used in this study to simulate engine responses, and operational ability of the main engine in seaway was discussed.

These pioneering works are the starting points of this study. As the first step, the authors developed a marine diesel engine simulator for self-propulsion test in waves. In this paper, the development of the marine diesel engine simulator and its application to the self-propulsion test are reported. New experimental methodologies are also proposed for the estimation of actual sea performance of ships in design stage.