

SYSTEM MODELLING AND DESIGN OPTIMIZATION OF WIND SAILS AND ROUTE FOR WIND ASSISTED SHIP

Cem Guzelbulut, Shun Ogawa, Katsuyuki Suzuki

The University of Tokyo

Keywords: Wind Assisted Ship, System Modelling, Optimal Sail Design, Optimal Route Design, Proximal Policy Optimization

Abstract

Increasing greenhouse gases emission pushes all industries to develop environment-friendly technologies. Wind assisted ships are one of the solutions in the way of decarbonized societies. Instead of fossil fuel consumption, wind energy can be used to assist ship propulsion and reduce fossil fuel consumption by replacing it to a renewable and clean energy. Different types of wind sails, such as rotor sails, rigid wing sails, kites, etc., were developed to use wind power. However, it is yet unclear which system provides the maximum benefit to reduce fuel consumption and how the design of wind sails affect the performance of wind sailing systems.

In this study, we have modelled hull, propeller, rudder, and wind sails based on MMG (Motion manoeuvring group) model. A Simulink model was created and controllers for rudder angle, propeller speed, wind sails were integrated. First, PID (proportional-integral-derivative) controllers were tuned to follow a given route. After building MMG model and controllers for rudder and propeller, lift and drag coefficients of a rigid wing sail were obtained by using an open-source airfoil characterization software depending on the angle of attack. Then, an optimization study was conducted to find the optimal airfoil shape for specific ship under different routing options. The chord length, thickness, the position of the maximum thickness of airfoil were considered as design variables to determine the shape of the airfoil. Propeller power consumption and rolling stability were considered as objective function and constraint equation, respectively. The effects of different airfoil geometries on the performance of wing sails were investigated. Besides, different controlling strategies to determine angle of attack of wind sails were examined to obtain the maximum reduction in propeller power. To conclude, present study investigates how wing sail affect ship performance, how much reduction in propeller power can be achieved by optimizing wing sails and the effect of different controlling strategies to determine angle of attack simultaneously.

Also it is important to find optimal route under given wind conditions to reduce GHG gas. To find optimal route of ship under wind condition, deep reinforcement learning method, Proximal Policy Optimization(PPO), is used because of its stability,

reliability and adaptability. The results show that when the time constraint of the voyage is not taken into account, the ship always maintains the lowest ship speed thus consuming the least amount of energy. The optimized route saves more energy compared to the baseline. When considering voyage time constraint, the ship starts to increase its speed and is able to reach the goal of the voyage around voyage time constraint and is able to save energy compared to the baseline. In order to validate the model, the paths generated by the reinforcement learning method are re-simulated using the wind-assisted ship MMG model, so that we can know how ship power will consume. The results also show that the model is able to save energy consumed during navigation.