System Modelling and Design Optimization of Wind Sails Under Different Sea and Wind Conditions

MARINE 2023

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ABSTRACT

Increasing greenhouse gases and CO2 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 developed by Japanese naval architects [1][2]. 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 XFOIL 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.

REFERENCES

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