An investigation on the hydrodynamic resistance of calcareous marine biofouling using high-fidelity simulations

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ABSTRACT

It is well established today that biofouling on ships increases the hull roughness, causing increased frictional resistance and fuel consumption, as well as decreased top speed and range. Antifouling (AF) coatings have been widely used to control the problem but they contain biocides which are toxic to marine organisms and may impact non-target species. The latter resulted in a worldwide ban on these coatings for all vessels. Their primary replacement, copper-based paints, are not as effective in controlling fouling. As research on non-toxic alternatives is ongoing there is a pressing need to develop predictive tools that can assess the impact of various types of fouling and coverage level on the frictional resistance of naval vessels. This way quantifiable and cost/efficient hull cleaning decisions can be made.

In this work we have generated biofouled surfaces with controlled surface statistics, which are representative of the ones on actual ships. The coverage, roughness high, skewness, and effective slope are among the statistics that are systematically varied. Since our focus in calcareous biofouling the building blocks in the surface synthesis are barnacles, tubeworms and oysters. The generated surfaces are then tested to illuminate which surface features, beyond percent coverage and type, are hydrodynamically significant. The bulk of the testing will be conducted in a channel flow configuration to establish the relation between the roughness function, ΔU, and the equivalent sandgrain roughness, k_S, for the different roughness types. All computations will be done using our in-house immersed boundary solver [1]. A detailed validation of the solver for turbulent boundary layers evolving over barnacles has been conducted by direct comparison to experiments [2,3].

The DNS database will answer fundamental questions related to the hydrodynamics of calcareous-fouling and identify scaling laws that enable extrapolation of laboratory data to field conditions. Emphasis will be placed on illuminating the basic mechanics of foul removal by hydrodynamic shear. We will consider single elements or larger topographical areas and compute the detailed forces acting on the elements and torque they generate at the base of the elements. Detachment happens when the torque from external forces overcomes the torque from adhesion force. The challenge will be to express the total torque in terms of local parameters (i.e. shear rate), which will have enormous impact in the AF coating design.

REFERENCES

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