Improved methodology for estimating the drag penalty due to hull roughness: Part I current challenges, roadblocks and proposed solutions.

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Abstract

There exists an extensive literature on turbulent boundary layers developing over rough surfaces, dating back almost 90 years to the seminal work of Nikuradse (1933). This problem is pertinent to ship operations where fouling on the hull can lead to very large increases in the skin friction drag coefficient (>80%, see Schultz et al., 2011). However, current engineering approaches to estimate this drag penalty face numerous challenges / roadblocks which influence the efficacy of these methods. Part I of this talk will discuss these challenges and introduce a campaign of field and laboratory measurements that can redress these issues. Part II will present preliminary results.

These challenges can be loosely distilled into four areas. (i) To predict the altered evolution of turbulent boundary layers (TBL) over a roughnened hull requires the establishment of a dynamic roughness length (often encapsulated in the equivalent sandgrain roughness k_s). However, this quantity is not directly observable from the hull topography, but is instead a fluid property that quantifies the effect that the surface topography has on the TBL. Though numerous empirical correlations have been proposed to relate the topography to k_s, few have been developed and tested specifically for marine biofouling scenarios. We propose here a series of field and laboratory experiments that will provide accurate training data to enable refinement of these correlations. (ii) Such correlations predict k_s as a function of topographical properties. Present practice in industry does not provide a full quantitative record of hull topography during inspection and we propose a novel surface scanning device to redress this issue. (iii) Even when k_s is known accurately, the efficacy of full-scale predictive methods (which typically integrate the drag contribution from a modeled TBL evolving over an appropriately roughened flat-plate) remain untested. We propose a validation method by which the k_s of an operating vessel will be precisely characterised (through imprints and surface scans taken from the hull, which are subsequently scaled and replicated for detailed laboratory experiments). Using laser-based flow diagnostics, we will also measure the state of the TBL over the hull of the operating vessel, comparing these measurements against the full-scale predictions. Finally, (iv) most current engineering tools for predicting TBL drag due to surface roughness assume a homogeneous coverage of the roughness. In reality, the roughness that forms on the hull of a ship due to biofouling is highly heterogeneous (or patchy). We propose refinements to current approaches for prescribing an effective roughness length under such heterogeneous operating conditions.

References

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