Fuel efficiency and fouling control coatings in maritime transport

First, this thesis concerns the drag performance of fouling control coatings (FCCs) used to protect hulls on ships against biofouling and, therefore, minimize any drag therefrom. A systematic overview of the literature and description of the experimental methods used to quantify the drag of FCCs has been made. Also, the advantages and disadvantages of the reported methods are listed; these provide an assessment of the most efficient methods to quantify the drag performance of FCCs. In addition, the main parameters impacting FCCs and the main findings for the drag performance of the mostly used FCC technologies are outlined. It was found that the drag performance of FCCs varies, depending on whether the FCC has been newly applied, has experienced dynamic exposure, or has experienced static seawater exposure. The summarized data revealed that the most common drag performance method currently used consists of measuring drag when coatings are newly applied and after static exposure. It was found that the main limitation of this method primarily arises due to incorrect exposure conditions, when compared to larger commercial ships that mainly are moving with few and shorter idle periods. As a result, it was determined that other methods must be explored in order to accurately measure the long-term drag performance of FCCs in conditions that mimic those encountered by ships’ hulls during actual voyages.

In an experimental study, five commercial FCC systems were applied to smooth disks with a radius of 11.45 cm. The drag performances in the newly applied coating condition and after one month of static immersion in natural seawater were measured using a friction disk machine (FDM). The four best performing coatings were re-examined for their drag performance after an additional 2.5 months of immersion. The five FCCs in the newly applied coating condition when applied on completely smooth substrates revealed a small difference and, in most cases, one that was less than the experimental uncertainty. After one month of static immersion, the hydrogel-based fouling release coating (FRC) with biocides had the lowest drag, while the fluorinated FRC had the highest drag. The hydrogel-based FRC without biocides and the two self-polishing copolymer (SPC) coatings showed intermediate performances. After 3.5 months of static immersion, the two hydrogel-based FRCS showed superior drag performance, compared to the two SPC coatings. Furthermore, the drag performances of two different FCC systems with varying substrate roughness values (i.e., the roughness below the coating system) were measured in the newly applied condition. An increase in the substrate roughness led to increased drag for both FCC systems, but the FRC was impacted less by the higher substrate roughness than the SPC coating.

To overcome the limitations from investigating only the drag of newly applied coatings and coatings after static immersion, an experimental setup was designed and built to estimate the changes in the skin friction of four FCCs over an extended period of time in conditions simulating the vast majority of ship profiles (i.e., speed and activity) in the present market. The setup consisted of two separate parts; one part aged FCCs directly in seawater in a dynamic manner similar to that experienced by a ship’s hull, and a second, laboratory part measured the torque (drag) of coated cylinders in a rotary setup. Four commercial FCCs were exposed for 53 weeks in Roskilde Fjord, Denmark, i.e., in relatively cold seawater (salinity of 1.2 wt%), from the spring of 2013 to the autumn of 2014. The in situ immersion conditions consisted of five-week cycles. Two weeks consisted of static immersion. This was followed by three weeks of dynamic immersion, in which the cylinders were rotated in natural seawater at a tangential velocity of 8.1 knots. It was found that the skin friction generally increased more during the static immersion, as opposed to the dynamic exposure, which revealed the need for exposure conditions that mimic those of larger commercial ships. Furthermore, with regard to the entire exposure period, it was found that the skin friction of the investigated FCCs decreased in the following order: fluorinated FRC (highest skin friction), hydrogel-based FRC without biocides, silylated acrylate SPC coating, and hydrogel-based FRC with biocides (lowest skin friction). However, the differences in skin friction between the latter three coatings were found to be small and often within the experimental uncertainty. After 25 weeks of immersion and mechanical cleaning, the differences in skin friction were, on average, less than 1%, i.e., within the experimental uncertainty, for velocities relevant for larger commercial ships. The roughness parameters, Rt(50) and Rz, were found to be poor indicators of the drag performance in new and after static exposure. It was found that the main limitation of this method primarily arises due to incorrect exposure conditions, when compared to larger commercial ships that mainly are moving with few and shorter idle periods. As a result, it was determined that other methods must be explored in order to accurately measure the long-term drag performance of FCCs in conditions that mimic those encountered by ships’ hulls during actual voyages.

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