Leveling and Drag Force Studies for Antifouling Coatings - DTU Orbit (07/10/2019)

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Biofouling, defined as the accumulation of marine species on ship hulls, causes a series of consequences, such as extra drag resistance, fuel consumption, and thereby emission of harmful gases (CO₂, SO₂, and NOₓ). To combat biofouling, fouling control coatings (FCCs) are widely applied on ship hulls. Two main types of FCCs are commercially available. The conventional antifouling (AF) coatings release biocides to control biofouling. Fouling release (FR) coatings limit biofouling mainly through the smooth surfaces which make it difficult for marine species to adhere with the help of the hydrodynamic force of seawater against the hull of a travelling vessel. Due to the high pigment amount, the conventional AF coatings have rougher surfaces than FR coatings.

Besides biofouling, the ship hull surface conditions, such as rough top FCC surfaces and surface irregularities (e.g., welding seams), also increase the drag resistance. Moreover, rough coating surface affects the esthetics and constitutes sites of weakness, i.e., potential starting points for corrosion, cracking, blistering and biofouling. Consequently, the FCC surface condition is of significant importance in the performance of marine vehicles. Therefore, the final goal of the PhD project is to decrease FCC surface unevenness and thereby the drag resistance. For most coatings, this can be achieved by improving the leveling properties of FCCs.

As the first step, the drag performance of newly applied AF and FR coatings were compared using a pilot-scale rotary setup. Results revealed that FR coatings caused less skin friction than AF coatings. The effects of water absorption on coating surface and frictional resistance were investigated through immersion experiments and standard water absorption tests. Although water absorption amounts for both AF and FR coatings were found to be prominent, the effects of water absorption on drag performance were insignificant for FR coating and water absorption reduced the skin friction of AF coatings. In addition, the effects of welding seams (including welding seam height and density) on drag resistance were thoroughly studied using both experiments with a designed flexible rotor and computational fluid dynamics (CFD) simulations. Significant effects were revealed for both welding seam height and density, especially at high speeds.

Therefore, the welding seam height is suggested to be controlled below 5 mm during ship construction to minimize drag resistance and achieve considerable economic benefits. Practically, welding seams can be ground to below 5 mm for the existing ships. Furthermore, experimental results indicated that FCC surfaces led to higher drag resistance than welding seams with seam height below 5 mm at full-scale welding seam density condition. Moreover, CFD results showed that frictional resistance mainly resulting from ship hull surfaces was the dominating one to the total drag resistance. Thus, FCC surface conditions were confirmed to be crucial and should be improved to minimize the friction and fuel consumption.

Therefore, the following work was to study leveling of liquid coating film to explore methods to improve leveling properties of conventional AF coatings. In all studies, model and commercial AF coatings have been used in experiments with solvent evaporation process involved. As the first step, the rheological effects of coating formulation ingredients on leveling were studied using an advanced rheometer. The shear changing process from application to the subsequent leveling was simulated using flow peak hold and flow sweep tests. It was found that rosins had insignificant rheological effects on the binder systems. In addition, it was inferred that, besides thixotropic agents, some other ingredients in the formulation may have thixotropic effects, such as reaction products between pigments and rosins or additives (e.g., wetting agents). The obtained results from rheological studies were found to be valuable input to coating formulation development work and the obtained dynamic data of film thickness, wavelength, waviness, and viscosity during leveling process after application, semi-empirical models were developed for describing leveling kinetics of a model AF coating and a commercial AF coating. However, it was not entirely possible to develop a universal model for leveling process because viscosity related rheological behavior varies with formulations containing different additives.

In summary, the drag resistance studies of FCC surfaces and welding seams confirmed the importance of improving hull surface conditions. Improving leveling properties was proved to be a possible way to reduce surface unevenness of AF coatings. However, the inherent sagging problem should always be controlled during leveling improvements in terms of formulation optimizations. Viscosity was concluded to be the most important controlling parameter for both leveling and
sagging. Therefore, rheological studies are necessary and special attention should be paid to the solvent evaporation process. Moreover, the effects of the spraying application process on leveling should be considered in the future work.

**General information**

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