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Slippery-liquid infused porous surfaces (SLIPS) have provided a new research direction in bioinspired materials. These composite materials are done starting from a micro/nanostructured surface, metallic or polymeric, in which an appropriate liquid is infused. The liquid penetrates into the surface pores and it is trapped by the surface morphology. In the present study SLIPS are examined in light of their possible use for drag reduction in naval applications; in fact, the interface with the seawater is mainly due to the infused liquid, inducing a relevant drag reduction. The paper reports a method for the preparation of a SLIPS starting from 1000 series aluminum plates of about 20 cm^2, i.e., in lab scale; then it is reported its characterization in terms of anticorrosion properties by EIS and anti-drag performances by rheometric tests. In addition, the attempt to realize the SLIPS in a bigger scale was done; the specimen was a 3 m2 panel, analyzed to determine its anti-drag performance in a towing tank. In lab scale the SLIPS did not result a protective treatment, but the drag reduction was about 14%. In the towing tank it was possible to discriminate the drag resistance of the SLIPS with respect to a standard aluminum plate, generally used for mega yacht hulls, and a painted steel plate, generally used for ships, but the SLIPS did not reduce the drag as in the lab experiments.

KEYWORDS: SLIPS, EIS, DRAG REDUCTION

INTRODUCTION

The resistance to motion of ships is due to two main effects: friction and wave-making. The relative importance of the two phenomena depends on the hull geometry, the characteristics of the ship motion and the sea state. For a large cargo ship advancing at a relatively low speed on a strait course in still water, frictional effects can exceed 90% of the total resistance, percentage decreasing for higher relative speed, motion complexity and sea roughness. For a few decades empirical formulations have been available to account for hull roughness when scaling experiments carried out on smooth, small scale hull models to rougher full scale technical surfaces in 'as built' conditions. These conditions include the standard surface finishing of rolled plates used in shipbuilding, but also the contributi[illegible]oughness from out of planeness of the hull [illegible] welds or lap joints always present in the hull [illegible]g. The same formulations can be adopted to pre[illegible] further increase in resistance due to degrada[illegible]cts like corrosion and wearing or to fouling, all implying an increase [illegible] of the hull.

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It is important to note that the direct relation between friction coefficient and surface roughness applies to what could be defined as 'macro-roughness'. Within this range, the leading concept for the control of surface characteristics can be summarized as 'the smoother, the better'. In recent years the controlled presence of micro- or nano-metric protrusions in the wall surfaces seems to offer, on the contrary, new possibilities for drag reduction, superhydrophobic surface. In addition, composite materials done starting from a micro/nanostructured surface (metallic or polymeric) in which an appropriate liquid is infused (the liquid penetrates the surface pores, and it is trapped by the surface morphology) can induce a relevant drag reduction, but also an effective anti-fouling action; slippery liquid infused porous surface, SLIPS [1-4]. In the present work it is reported the method for the preparation of a SLIPS starting from series 1000 aluminum alloy plates of about 20 cm dimensions of the rectangular vessel, the location of the free surface (reference plane), and the dimensions of the disk rotors are given at the following link [3], where the interested reader can access complete details of the geometry. All measurements were performed at a rotor's immersion depth of 40 mm. The contribution of the rotating shaft to the total torque is negligible with respect to that of the disk, and inferior to the error bar in the experimental data.

The Reynolds number Re and the moment coefficient C_m are defined as [5]:

$$Re = \frac{\omega R^2}{\nu} \quad (1)$$

$$C_m = \frac{M}{\frac{1}{2}\rho\omega^2 R^5} \quad (2)$$

where is the angular velocity (rad/s), R is the rotor radius (m), is the cinematic viscosity of water (m^2/s), M is the measured torque (Nm), and is the density of water (kg/m^3).

The SLIPS was prepared on a separated disk of aluminum with the same rotor's diameter and a thickness equal to 1.5 mm. Subsequently, the SLIPS support was attached to the bottom of the rotor, obtaining a rotating device with a total thickness of 3.3 mm (considering 0.3 mm of silicone gel used for the bonding), named two layers configuration (Fig. 2, two layers), in which only the lower surface was SLIPS, while the lateral and the top surfaces, as well as the rod, were of the same non treated aluminum used as reference. For this reason, the SLIPS sample is not available with the one-layer configuration. Also, a three layers configuration (5.1 mm in thickness), in which a second SLIPS support disk was applied on the top of the rotor was prepared. In this case, only the lateral surface and the rod were not treated (Fig. 2, three layers).

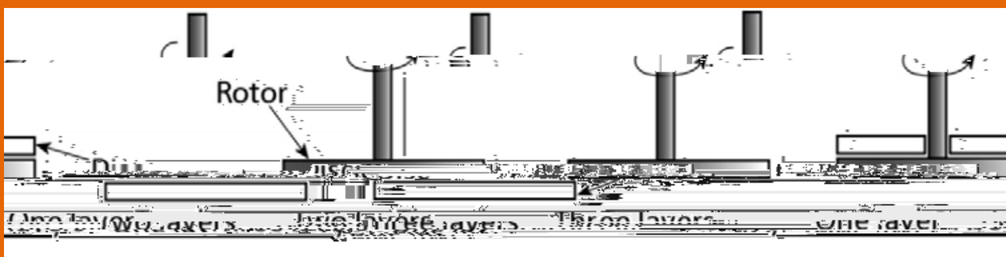

Fig.2 - Different rotors configuration used for the rheological tests in immersion.

In the last two cases the SLIPS results have always been compared to untreated disks of equivalent thickness.

The sheets were tested in the Università degli Studi di Napoli "Federico II" Towing Tank at the Department of Industrial Engineering (Fig. 3a). The tank measurements are length of 136.0 m, width of 9.0 m and depth of 4.5 m, the carriage maximum speed is 10.0 m/s.

a) b)

Fig.3 - Towin [redacted] on and a tested plate.

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Surveys with towing tank are carried out by means of a carriage moving on rails placed on the longitudinal walls of a rectangular basin.

In resistance tests, the carriage tows the model in uniform and rectilinear motion. The models are constrained to the carriage with load cells that provide the necessary data. For testing the plate, the dynamometer shown in Fig. 3b was designed and built. The device has been designed to obtain optimal alignment of the plate with the direction of motion minimizing the angles of incidence of the flow which would cause additional resistance components. The dimensions of the plates tested in the Towing Tank allow to reach Re close to the typical values of full-scale ships (~10^8). In the specific case, the length of the plates - 3.00 m - and the speed - 5.0 m/s - allowed to reach Re = 1.4 x 10

The trends of the moment coefficient C_m as a function of the Reynolds number Re are similar for all disk thicknesses (Fig. 5), and, not unexpectedly, C_m increases monotonically, at each Re, with the thickness of the disk rotor. This is related with the extra drag occurring along the lateral surface of thicker disks.

Fig. 6 shows the moment coefficient C_m against Reynolds number Re for the LIS treatment [1] and the bare aluminum surface corresponding to the two- and three-layer.

The values of moment coefficient C_m are consistently

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