An assessment of skin-friction drag over a recently cleaned ship under steady cruising via a combination of in-situ laser based measurement, laboratory experiment, Computational Fluid Dynamics (CFD) and empirical estimation .

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The hull of a recently dry-docked ship is expected to be relatively smooth; however, closer inspection shows that it can exhibit an "orange-peel" roughness pattern. Here, four different experimental/analytical techniques are applied to estimate the equivalent sand-grain roughness height k_s and the associated drag of a recently cleaned and painted Ro-Ro ferry hull. The four techniques are:

1. **In-situ Laser Doppler Anemometer (LDA)**: A small glass window is placed on the double-bottom hull of the Ro-Ro ferry, allowing the LDA to measure the velocity gradient in the turbulent boundary layer formed over the hull.
2. **Laboratory measurement**: The surface roughness pattern from a recently cleaned and painted Ro-Ro ferry hull is obtained using an imprint of silicone rubber during dry-docking. The imprint is then scaled and replicated to cover the working section of a wind tunnel for rough-walled boundary layer experiments using a Hot-wire Anemometer.
3. **Computational Fluid Dynamics (CFD)**: The digital scan of the roughness is used for simulation study via the Reynolds-averaged Navier–Stokes (RANS) method.
4. **Empirical estimation**: The digital scan is applied to two mathematical models: Chan et al. (2015) and Forooghi et al. (2017). Both methods are known to estimate the increase in drag penalty from an orange peel type of roughness.

Initial assessments of the four independent methods show that the hull would experience around 25%-37% increased drag. This result indicates that even a recently cleaned and painted hull would already experience significant drag. This study highlights the sobering challenges facing the shipping industry in dealing with surface roughness.

Chan L, MacDonald M, Chung D, Hutchins N, Ooi A. 2015. A systematic investigation of roughness height and wavelength in turbulent pipe flow in the transitionally rough regime. J Fluid Mech. 771:743–777.

Forooghi P, Stroh A, Magagnato F, Jakirlic S, Frohnapfel B. 2017. Toward a universal roughness correlation. J Fluids Eng. 139: 121201.

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