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A Stokes flow based roughness metric SHAN YANG, GEORG STADLER, OMAR GHATTAS, ROBERT MOSER — One of the difficulties with evaluating the effects of roughness on wall-bounded flows is that the commonly used metric for roughness height, the equivalent sand-grain roughness height, is determined not from the topography of the roughness, but from the measured effect of the roughness on the flow. It would be much more useful if the effects of roughness could be predicted directly from the roughness topography. As a step in this direction, we examine the effects of boundary roughness on the drag in Stokes flow. The first and second order shape derivatives of the mapping from roughness topography to drag are derived analytically. Not surprisingly, it is found that a flat wall is a stationary point (a minimum) of this mapping. The eigenfunctions of the shape Hessian of the drag are Fourier modes, and the sensitivity of the drag is approximately linear in the wavenumber. These results provide a topographically determined roughness metric, which for Stokes flow is predictive of the effects of roughness on the drag. While not analytically justified, this metric may also be useful for more general flows. This is investigated by analyzing specified roughness topographies, for which experimentally determined equivalent sand-grain roughness heights are available in the literature. This general approach of evaluating roughness effects through analysis of the shape derivatives of the drag can also be applied to the Navier-Stokes equations, even for turbulent flows.

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