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Effects of pressure on wetted area of submerged superhydrophobic granular coatings. Part II: poly-dispersed coatings

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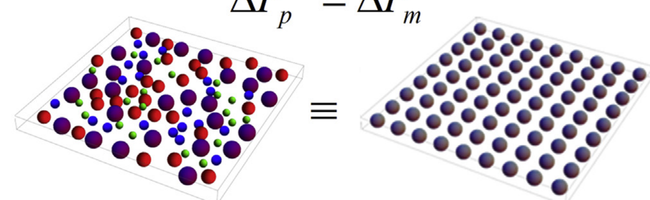
HIGHLIGHTS

- New formulations to characterize performance of superhydrophobic coatings.
- Predictions of wetted area and hydrostatic critical pressure for the coatings.
- Wetted area is important for predicting the water drag force on a surface.
- The proposed method is analytical, easy to use, and relatively accurate.
- Includes poly-dispersed coatings of randomly distributed heterogeneous particles.

GRAPHICAL ABSTRACT

A simple method is developed to characterize the wettability of superhydrophobic coatings comprised of poly-dispersed particles of different diameters and contact angles by defining mono-dispersed equivalent particle diameters and contact angles for such poly-dispersed coatings.

$$\Delta P_p^{cr} = \Delta P_m^{cr}$$



$$n_1 = n_2 = n_3 = n_4 = 0.25$$

$$\theta_1 = 120^\circ, \theta_2 = 100^\circ, \theta_3 = 80^\circ, \theta_4 = 60^\circ$$

$$d_1 = 72,\ d_2 = 57,\ d_3 = 40,\ d_4 = 31\ \mu\text{m}$$

$$\theta_{eq} = \frac{2\pi\cos\theta_i + \sum_{j=1}^{k}\beta_{ji}\cos\theta_j}{k\pi} = 107^\circ$$

$$d_{eq} = \frac{2\pi d_i + \sum_{j=1}^{k}\beta_{ji}d_j}{k\pi} = 63\ \mu\text{m}$$

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ABSTRACT

The effects of hydrostatic pressure on the stability of the air–water interface over submerged superhydrophobic coatings comprised of mono-dispersed particles was studied in the first part of this two-part publication [Colloids and Surfaces A, 465 (2015) 87–98]. In this second part, our formulations are extended to cover granular coatings comprised of randomly arranged particles having bi-dispersed or poly-dispersed size and contact angle distributions. Simple analytical formulations are developed to predict how the air–water interface transitions from a non-wetted (Cassie) state to the fully-wetted (Wenzel) state through a series of intermediate wetting states. In particular, a simple mono-dispersed equivalent particle diameter is proposed to be used in predicting the critical pressure and wetted area of poly-dispersed coatings comprised of particles of different diameters and contact angles as a function of hydrostatic pressure. Numerical simulations conducted via the Surface Evolver finite element code have been used to examine the accuracy of the analytical formulations developed in this study.

1. Introduction

The reduced cost of manufacturing has played an important role in making spray-on granular superhydrophobic coatings attractive alternatives to superhydrophobic surfaces produced via microfabrication (see e.g., [1–3]). Such surfaces can be used for applications ranging from self-cleaning and drag reduction to corrosion resistance and heat transfer [4–7]. The essential attribute of superhydrophobic (SHP) surfaces is the reduced water–solid contact area (wetted area), which helps to reduce the friction between a moving body of water and the surface [6–9]. An analytical force

Abbreviations: AWI, air–water interface; CCP, critical capillary pressure; CHP, critical hydrostatic pressure; FB, force balance; IA, immersion angle; SVF, solid volume fraction; YLCA, Young–Laplace contact angle; SE, Surface Evolver; ED, equivalent diameter; VED, Voroni equivalent diameter.

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