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Development of Surface Structures for Large Effective Slip: How Much Slip Is Possible in Ideal, Lab and Real Conditions?

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An ideal condition to reduce the drag of a liquid flowing on a solid surface is maintaining a lubricating gas layer between the solid and the liquid. For water flowing on a 1 or 10 μm-thick air layer, for example, the slip length is calculated to be roughly 50 or 500 μm, respectively - large enough to benefit a wide range of engineering applications. Unfortunately, however, the above ideal water-levitating condition is only imaginary, because such a liquid-gas meniscus cannot be sustained in nature. Instead, water-repelling structured surfaces bring us closer to the imaginary condition by minimizing the liquid-solid interface and keeping the water mostly on a layer of air. The underlying goal in developing a large-slip surface is, therefore, to create a condition as close as possible to the uniform air lubrication, which is often overlooked. For example, while a large contact angle on a superhydrophobic surface helps keep the liquid fakir, note that once levitated, the contact angle has little effect on increasing the slip length. Instead, the geometrical parameters of the surface structures, e.g., air fraction, pitch and depth of the structures, are the determining factors. A series of development efforts to create surfaces that bring us closer to the ideal air-lubricating condition will be presented, with the slip length currently measured as large as 400 μm. However, it will be also noted that they are valid only in laboratory conditions, where the sample is fabricated to near perfection and the pressure in the flowing liquid is under strict control. In real-life engineering conditions, which include high and fluctuating pressure, defective surfaces, and liquids full of impurities and particles, it remains to be seen if we will ever be able to create a slip surface that can be field-deployed - a millennium-old dream.