Nanobubbles explain the large slip observed on lubricant-infused surfaces

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Lubricanat-infused surfaces, in which a liquid lubricant is trapped within surface roughness, hold promise to reduce the huge frictional drag that slows down the flow of fluids at microscales,[1] but their mechanism of action is not yet understood[2-4]. We show that infused Teflon wrinkled surfaces induce an effective slip length 50 times larger than expected based on the presence of the lubricant alone (b = 5 μm for the flow of water, equivalent to $12 \pm 3\%$ drag reduction). This effect is particularly striking as it occurs even in situations when the viscosity of the infused lubricant (silicone oil $\mu_o = 10$ cSt and 5 cSt, hexadecane $\mu_o = 4$ cSt) is several times higher than that of the flowing liquid (water, $\mu_w = 0.89$ cSt). Crucially, the slip length is observed to increase with increasing air content in the water but is much higher than expected even in degassed and plain Milli-Q water [5]. Imaging directly the immersed interface using a mapping technique based on atomic force microscopy meniscus force measurements [6,7], we reveal that the mechanism responsible for this huge slip is the nucleation of surface nanobubbles, which can be unequivocally distinguished from the infused lubricant. The large magnitude of drag reduction is quantitatively explained with the height and distribution of surface nanobubbles, and by a numerical model of flow on these composite surfaces. The presence of nanobubbles on lubricant-infused surfaces, and not the lubricant alone, explains the large drag reduction reported so far.

References

- Peppou-Chapman, S., Hong, J. K., Waterhouse, A. & Neto, C. Life and death of liquid-infused surfaces: a review on the choice, analysis and fate of the infused liquid layer. *Chem. Soc. Rev.* **49**, 3688-3715, doi:10.1039/D0CS00036A (2020).
- Kim, J.-H. & Rothstein, J. P. Delayed lubricant depletion on liquid-infused randomly rough surfaces. *Exp. Fluids* **57**, 81, doi:10.1007/s00348-016-2171-3 (2016).
- Solomon, B. R., Khalil, K. S. & Varanasi, K. K. Drag Reduction using Lubricant-Impregnated Surfaces in Viscous Laminar Flow. *Langmuir* **30**, 10970-10976, doi:10.1021/la5021143 (2014).
- Lee, S. J., Kim, H. N., Choi, W., Yoon, G. Y. & Seo, E. A nature-inspired lubricant-infused surface for sustainable drag reduction. *Soft Matter* **15**, 8459-8467, doi:10.1039/C9SM01576K (2019).
- Vega-Sánchez, C., Peppou-Chapman, S., Zhu, L.& Neto, C. Nanobubbles explain the large slip observed on lubricant-infused surfaces. *Nature Comm.* **13**, 351, doi:10.1038/s41467-022-28016-1 (2022).
- Peppou-Chapman, S. & Neto, C. Mapping Depletion of Lubricant Films on Antibiofouling Wrinkled Slippery Surfaces. *ACS Appl. Mater. Interfaces* **10**, 33669-33677, doi:10.1021/acsami.8b11768 (2018).
- Peppou-Chapman, S., Vega-Sánchez, C. & Neto, C. Detection of Nanobubbles on Lubricant-Infused Surfaces Using AFM Meniscus Force Measurements. *Langmuir* **38**, 10234-10243, doi:10.1021/acs.langmuir.2c01411 (2022).