Dependence of Drag Over Super Hydrophobic and Liquid Infused Surfaces on Substrate Asperities

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Why we care:

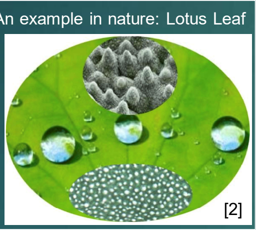
- Ships transport 90% of world goods
- Ships produce 3% of world pollution
- Friction causes 80% of ship resistance

Project Goal:

- Advance flow physics understanding
- Quantify drag penalty due to surface's roughness
- Provide manufacturing design criteria

Super-hydrophobic (gas-based) and liquid infused (lubricant-based) surfaces reduce drag

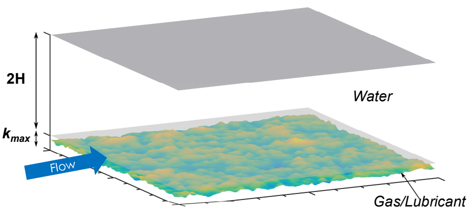
An example in nature: Lotus Leaf



[2]

The Naiver Stokes equations were solved using in-house CFD code for two fluid configuration:

- Finite difference method
- Level Set method
- Runge-Kutta method



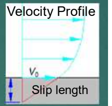
Results:

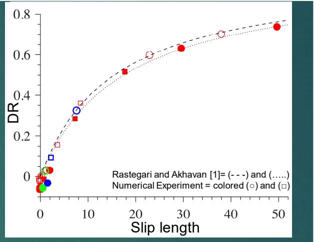
- DR = Drag Reduction

$$= 1 - \frac{\tau}{\tau_{smooth}}$$

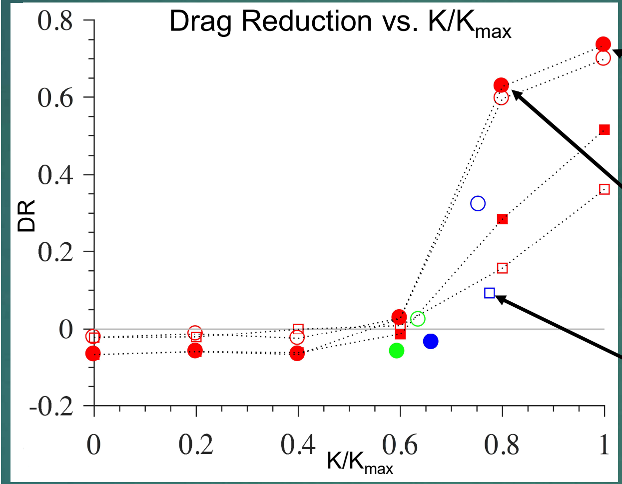
- τ = Shear Stress
- τ_{smooth} = Smooth Wall Shear Stress

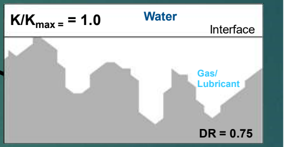
Rastegari and Akhavan's correlation between DR and slip length aligns well with in-house CFD simulations

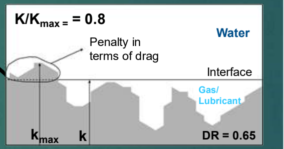


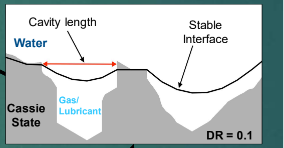


Rastegari and Akhavan [1]= (- - -) and (.....)
Numerical Experiment = colored (○) and (□)

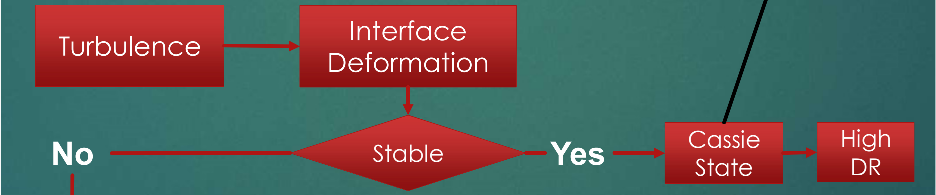








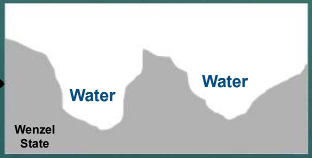
K/K_{max} ⬆ = Drag ⬆



Turbulence → Interface Deformation → Stable

Yes → Cassie State → High DR

No → Wenzel State → Low DR



Wenzel State

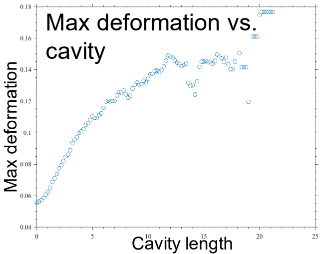
Water gets in

⬇

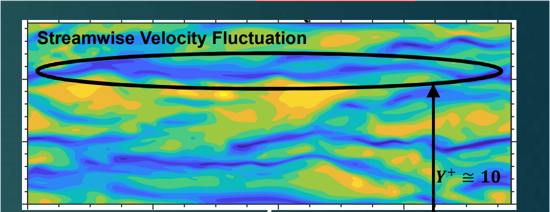
Loss of gas/lubricant

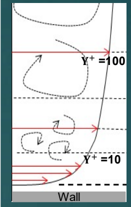
⬇

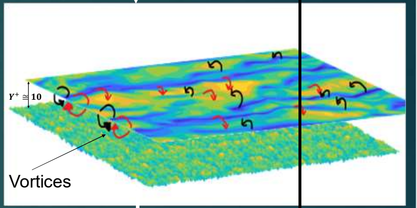
Drag increases

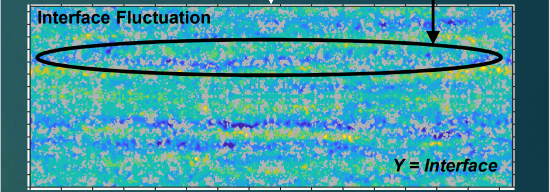


Cavity length ⬆ = Interface deformation ⬆









Streamwise Vortices

Interface deformations

Conclusions:

- Drag reduction of $K/K_{max} > 0.6$
- Streamwise vortices induce interface deformations

Small cavity

⬇

Small interface deformation

⬇

Large drag reduction

Acknowledgments:

- Special thanks to non-faculty advisor Ph.D Edgardo Garcia
- These results are under review for publication

References:

[1] A. Rastegari and R. Akhavan, Journal of FluidMechanics 773, R4 (2015).

[2] Y. Lin, H. Chen, G. Wang, A. Liu, Aihui, Recent Progress in Preparation and Anti-Icing Applications of Superhydrophobic Coatings (2018).