

DRAG REDUCTION OVER SUPERHYDROPHOBIC SURFACES WITH SINUSOIDAL TEXTURES

P.A. Fuaad* and K. Arul Prakash

Fluid Mechanics Group, Department of Applied Mechanics, Indian Institute of Technology Madras, Chennai 600 036, India

Keywords: *Turbulent, Drag reduction, Superhydrophobicity, Sinusoidal pattern*

Structured superhydrophobic surfaces allow liquids to slip over the air film trapped inside textured grooves, providing immense skin friction gains compared to a smooth wall. Previous studies indicate a significant drag reduction for streamwise aligned and post-shaped textures while an increase in drag is observed for spanwise aligned ridges [1]. The present investigation focuses on the capability of enhanced drag reduction over streamwise aligned sinusoidal ridge patterns. In a turbulent flow, the effect of superhydrophobic surfaces is confined to a thin surface layer of the order of the width of protuberance features, limited within the viscous sublayer. In this surface layer, in contrast to straight ridges, sinusoidal ridges can induce a small amount of asymmetric lateral secondary flows, emulating the effect of known drag reduction mechanism by lateral wall oscillations [2]. A series of Direct numerical simulations (DNS) is employed for the investigation of drag reduction in a fully developed turbulent flow in a superhydrophobic channel at a friction Reynolds number ($Re_\tau = 180$). For calculating the slip length and the resulting drag reduction, the fractional step method is implemented with a semi-implicit time advancement where viscous terms are computed using the Crank-Nicolson scheme while an explicit second-order Adams-Bashforth method is used for the convective terms. A spanwise deviation ($z'(x)$) from the straight ridge is introduced in the form of $z'(x) = a \sin\left(\frac{2\pi}{\lambda}x\right)$. The wavelength (λ) and amplitude (a) are varied such that the maximum slope ($\frac{2\pi a}{\lambda}$) of the sinusoidal curve remains fixed corresponding to an angle of 11.3° . The streamwise phase-averaged velocity profiles show that the spatial oscillations of spanwise velocity are successfully induced. Small wavelengths lead to an increase in drag compared to the straight ridges while overall higher drag reduction is achieved for larger wavelengths. These results show that, even though the slip lengths are lesser than the straight ridges, the lateral oscillations generated over the sinusoidal ridges influences the percentage drag reduction achieved.

REFERENCES

- [1] Kevin B Golovin, James W Gose, Marc Perlin, Steven L Ceccio, and Anish Tuteja. Bioinspired surfaces for turbulent drag reduction. *Phil. Trans. R. Soc. A*, 374(2073): 20160189, 2016.
- [2] Quadrio, Maurizio, Pierre Ricco, and Claudio Viotti. Streamwise-travelling waves of spanwise wall velocity for turbulent drag reduction. *Journal of Fluid Mechanics*, 627:161–178, 2009.