Physics and Control of Wall Turbulence

John Kim*

Department of Mechanical and Aerospace Engineering
University of California, Los Angeles
Los Angeles, CA 90095
*Correspondent author: jkim@seas.ucla.edu

The control of turbulent boundary layers (TBLs) requires a thorough understanding of the underlying physics of TBLs, and an efficient control algorithm, both of which have been less than satisfactory despite the great interest they have garnered over the years. Much progress on both fronts have been made through the advancement in computational fluid dynamics and control theories. An overview of the author's work on turbulence control aimed at achieving viscous drag reduction in turbulent boundary layers will be presented. The underlying physics of turbulence responsible for high skin-friction drag in TBLs will be discussed first, followed by different flow control strategies explored through numerical experiments. Examples of both active and passive controls will be presented. For active control, optimal surface blowing and suction were sought in an attempt to achieve drag reduction by suppressing near-wall turbulence structures. In particular, recognizing that the self-sustaining mechanism of near-wall turbulence involves linear process (Figure 1), control strategies to interfere this linear process were designed and applied, resulting in substantial skin-friction drag reduction (Kim 2011). Success and limitations will be discussed. For passive control, the effects of superhydrophobic surface (SHS) on turbulence structures and skin-friction drag will be presented (Figure 2). It was found that the effective slip length normalized by viscous wall units was the key parameter. It was shown that the effective slip length can be interpreted as the depth of influence in the wall-normal direction into which SHS can affect near-wall turbulence structures, and that the effective slip length should be on the order of the buffer layer in order to have the maximum benefit of drag reduction (Park et al. 2013).

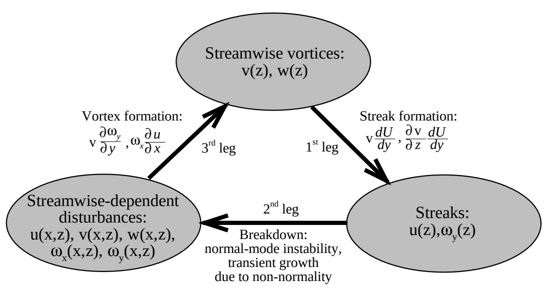

Figure 1: Schematic illustration of a self-sustaining process of near-wall turbulence structures.

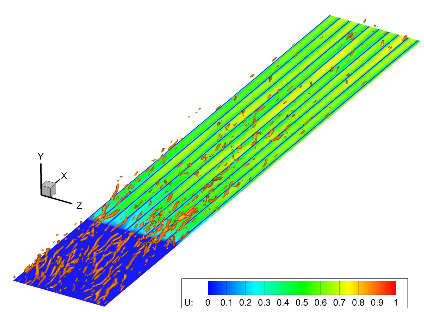

Figure 2: Isosurface of $\lambda_2 = -0.4$ and contours of the streamwise slip velocity over SHS ($Re_{\tau,\text{in}} = 200$, $GF = 0.875$). Contour levels are shown in the figure.

REFRENCES

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Park, H., Park, H. & Kim, J., 2013, "A numerical study of the effects of superhydrophobic surface on skin-friction drag in turbulent channel flow," *Phys. Fluids*, **25**, 110815.