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Turbulent Drag Reduction Using a Dynamic Free-Slip Boundary

Cong Wang

Research Engineer
Division of Engineering and Applied Science , California Institute of Technology, Pasadena, CA

ABSTRACT:

Wall-bounded turbulent flows generate large wall shear stress on the surface of commercial airplanes and ocean liners, which is responsible for a significant amount of the total energy expenditure. Over the past several decades, many promising turbulent drag reduction methods have been developed, such as a passive superhydrophobic surface or an actuated solid boundary. However, it is still challenging to generate sustainable drag reduction effect in high Reynolds number turbulent flows. Recently, we created a novel dynamic free-slip boundary method by dynamically modulating air-water interfaces that are attached to the solid boundary. This method can reduce the wall shear stress for more than 40%. We discovered convincing evidence for the strong drag reduction effect, such as the outward shifted vortical structures. Counter intuitively, a propulsion force (rather than drag force) is generated by the dynamic free-slip boundary and a local re-laminarization process is induced in the near-wall region. These intriguing phenomena are connected to the nonlinear oscillation of the dynamic free-slip boundary, which induces large-scale streaming motions (e.g., a streaming jet). Based on these physical observations, we propose a mechanism of turbulent drag reduction using the dynamic free-slip boundary. In addition to turbulence control, the dynamic free-slip boundary can be employed for engineering applications such as controlling mass and heat transfer process.

BIOGRAPHY:

Cong Wang is currently a research engineer at California Institute of Technology (Caltech). He received his B.Eng in Engineering Science from National University of Singapore in 2013, and his M.S. and Ph.D. in Aeronautics from Caltech in 2014 and 2019. His Ph.D. thesis focused on the manipulation of turbulent boundary layer using a dynamic free-slip boundary. His current research interest lies in the general area of turbulent drag reduction, flow control and bio-inspired intelligent systems. Cong is a recipient of the Ernest E. Sechler Memorial Award in Aeronautics in 2018 and the Donald Coles Prize in Aeronautics in 2019 from Caltech.