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Thermo-Aerodynamic Performance Sensitivity to Dimple's Design in Turbulent Channel Flow

Speaker: Prof. Khoo Boo Cheong
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Host: Dr. Lua Kim Boon

Speaker Biography:

Prof. Khoo Boo Cheong is a distinguished scholar in Fluid Mechanics and a global leader in advanced research on fluid-structure interaction, underwater shock dynamics, and multi-medium flows. He currently serves as the Director of Temasek Laboratories and the Temasek Defense Systems Institute at the National University of Singapore (NUS). Additionally, he is a Professor in the Department of Mechanical Engineering at NUS's College of Design and Engineering and has served as Co-Chair of Computational Engineering programs under the Singapore-MIT Alliance.
With over 500 peer-reviewed journal publications and more than 480 conference papers, Prof. Khoo is an exceptionally prolific researcher with an H-index of 60 on Web of Science. His groundbreaking work has garnered prestigious awards, including the Royal Aeronautical Society Prize and the Defence Technology Team Prize.
Prof. Khoo is deeply involved in global scientific communities, serving on advisory boards and editorial committees for leading journals. His extensive research projects, funded by international agencies such as ONR and Qatar NRF, highlight his profound contributions to advancing science and engineering across disciplines.

Abstract:

Recent research on dimples highlights their potential to enhance heat transfer in turbulent channel flow with minimal drag increase, or even reduced drag with shallow dimples, leading to improved thermo-aerodynamic efficiency. This performance depends on dimple design parameters and flow conditions. To optimize dimple design, we investigate the effects of parameters such as shape, size, and edge ratio using wall-resolved Large Eddy Simulations (LES) for shallow dimples. All dimples have a 5% depth-to-diameter ratio with smooth, rounded edges, arranged in a staggered form to maximize coverage, and were studied at Reynolds numbers ≅ 180, 395, and 590. We find that changing the dimple shape from steep wall-slope (e.g., circular) to gentle wall-slope (e.g., diamond) reduces pumping power by ~ 11 - 13.1 %. Increasing dimple size or edge ratio also positively impacts pumping power. The Nusselt number improves by up to 10.2%, with steep wall-slope dimples showing the highest enhancement, while gentle wall-slope dimples exhibit lower heat transfer performance. The thermo-aerodynamic efficiency, measured by area and volume goodness factors, improved by up to 7.2% and 6.9%, respectively, with gentle wall-slope dimples achieving a higher area goodness factor and steep wall-slope dimples boosting volume goodness factor.