TEXAS TECH UNIVERSITY
Department of Mechanical Engineering

Ph.D. Defense Announcement

Some current topics in vortex dynamics and wall turbulent flow drag control

by

Jie Yao

Ph.D. Advisor: Fazle Hussain

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Abstract

Turbulent flows are often viewed as a tangle of vortices or composed of coherent structures, and much of turbulence physics is interpreted using the concepts of vortex dynamics. Hence, vortex identification and visualization are crucial, and have been the focus of numerous turbulent flow studies. A definition of vortex for hypertonic and multi-phase flows is defined and derived, and its applications for variety of flows are demonstrated. Vortex reconnection is a fundamental topology transforming dynamical event, playing a significant role in turbulence phenomena, such as energy cascade, fine-scale mixing, and noise generation. To shed light on the mechanism of reconnection on energy cascade, we studied viscous anti-parallel vortex reconnection by means of direct numerical simulation (DNS) for vortex Reynolds numbers Re_{Γ} up to 40 000. Our simulations not only reveal the detailed mechanisms of high Re reconnection, but also present the reconnection avalanche as a realistic physical model for turbulence cascade.

Control of turbulent boundary layers to reduce drag is important for energy saving and also for environmental pollution control. To address this, two independent ways of drag control are proposed and explored. First, drag reduction using a large scale spanwise opposed wall-jet forcing method is demonstrated and its efficacy is explored in a turbulent channel flow (TCF) at the friction Reynolds numbers Re_{τ}= 180 and 550. Second, to gain further insight into the effectiveness of drag control method at high Re_{τ}, the mechanism and effectiveness of drag reduction using spanwise wall oscillation (SWO) are pursed in a turbulent channel flow with Re_{τ} ranging from 200 to 2000, the latter being currently one of the largest Re considered in drag control. Based on our results, we predict that more than 10% drag reduction can be achieved at very high Reynolds numbers, say, Re_{τ} = 10^5. We also performed DNS for compressible TCF to establish how effective SWO is when a boundary layer is compressible and also to document its drag reduction trend with Mach number.