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Vortex reconnection and turbulence cascade

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ABSTRACT:

Vortex reconnection (VR) is a fundamental topology transforming dynamical event, playing a significant role in turbulence phenomena such as energy cascade, fine-scale mixing, and aerodynamic noise generation. In addition to its physical relevance, VR is also a stand-alone mathematical problem in studying finite time singularity of the Euler equation. Hence, VR has been extensively studied recently, both in classical and in quantum turbulence. We first summarize our prior (UH) results on viscous VR (mainly at low Reynolds numbers, Re = circulation/ viscosity), including its physical mechanism, scaling, and polarization and compressibility effects, etc. In pursuit of the role of VR in turbulence cascade, we have recently performed direct numerical simulation of anti-parallel vortex tubes up to Re = 40, 000, and show the first evidence of VR cascade scenario as the physical mechanism of turbulence cascade initially proposed by Melander & Hussain (1988, CTR Reports, Stanford U.), who suggested that the remnant threads undergo successive VR in a reconnection cascade. As Re increases, higher (e.g., third) generation of VR occurs, and the energy rapidly cascades to finer scales, forming a turbulent cloud avalanche consisting of slender rings and hairpins. A -5/3 spectrum follows the VR cascade. These results confirm our long-standing claim that VR is important in the elusive physical mechanism of turbulence cascade.

BIOGRAPHY:

Fazle Hussain's expertise is in vortex dynamics, turbulence, and measurement techniques, and is most known for his students' experiments and numerical analyses in fluid turbulence. He has also researched in solar energy, holography, flow noise, flow control, cardiovascular dynamics, and nanotechnology. He is now interested in fuel saving by drag reduction, wind turbine technology, cancer cell mechanics, and microseismology. Following his PhD in mechanical engineering in 1969 at Stanford, he was post-doc at Johns Hopkins, before joining UH, where he became professor in 1976, Cullen Distinguished Professor in 1989, until Cullen Distinguished University Chair in 2010. He joined Texas Tech University in 2013 as the President's Distinguished Chair in Engineering, Science & Medicine. He has been recognized by the four topmost awards in fluid mechanics: the Fluid Dynamics Prize (1998) of the American Physical Society (APS), the Freeman Scholar Award (1984) and the Fluids Engineering Award (2000) of ASME, and the Fluid Dynamics Award (2002) of AIAA. He served as the Chair of the Fluid Dynamics Division of APS, Chair of ME of NAE, and is a Fellow of APS, ASME and AIAA. He served as a Board Member of TAMEST and was a former recipient of UH's Farfel Award. He was the 2009 Moore Distinguished Scholar at Caltech, and is an Honorary Professor (for Life) at the Peking University (Beijing).