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Linear and Nonlinear Instability Modes of the Lamb-Oseen Vortex in a Finite-length Pipe

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Venue：Faculty of Engineering Bldg. 2, Room 31A

Abstract:

Rayleigh in 1917 showed a linear stability criterion that an axisymmetric base rotating flow in an infinitely long pipe was neutrally stable with respect to axisymmetric perturbations if the base flow circulation function K satisfied $\frac{1}{r^3}\frac{dK^2}{dr} \geq 0$. However, it is well-known from experimental work that instability and bubble breakdown appear under axisymmetric conditions contrary to classic stability theory. Recent works have demonstrated that the Rayleigh criterion is valid only when a swirling flow is in an infinitely long pipe or a finite-length pipe with periodic boundary conditions. Inlet and outlet boundary conditions critically alters the stability of the base swirling flow in a finite-length pipe. The Lamb-Oseen vortex is an analytical model for practical vortices. I will present our latest DNS simulation and analysis of the dynamics of the perturbations on a base Lamb-Oseen vortex flow with a uniform axial velocity entering a finite-length straight circular pipe. We identify different linear perturbation modes and the evolution to two types of final stable states: axisymmetric non-columnar flow and spiral breakdown flow. Complete evolution of small initial perturbations to such final stable states through linear and then nonlinear instability growth will be demonstrated. The stability boundary in the Reynolds number and swirl ratio plane will be mapped out. We also show the kinetic transfer mechanism of the perturbations by energy method based on the Reynolds-Orr equation to identify the instability origin.

Professor Feng Liu

Feng Liu: Professor of Mechanical and Aerospace Engineering at the University of California, Irvine. He received his B.S. from Northwestern Polytechnic University in Xi'an, China; M.S. from Beijing University of Aeronautics and Astronautics; and Ph.D. from Princeton University. He joined UCI as an assistant Professor in Fall of 1991. He was the recipient of the Outstanding Engineering Professor Award from the students of Class 2000 at UC Irvine. His research interests include computational fluid dynamics, aeroelasticity, turbomachinery, combustion, and propulsion. He is the author or co-author of more than 100 journal articles. Dr. Liu is a Fellow of AIAA and ASME. He served as the Associate Editor for Journal of Fluids Engineering, International Journal of Computational Fluid Dynamics, and Journal of Propulsion and Power (continuing). He received the 2023 AIAA Air-breathing Propulsion Award "for the turbine-burner engine innovation and other high-impact contributions of computational methods for turbomachinery aerodynamics."

主催：
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