Cymer Center for Control Systems and Dynamics

Dynamics and Control of Newtonian and Viscoelastic Fluids: A System-Theoretic Perspective

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Understanding the mechanisms causing transition to turbulence in wall-bounded shear flows is one of the oldest problems in fluid mechanics. In this talk, a system theoretic approach is used to model and analyze this problem in channel flows of both Newtonian and viscoelastic fluids. Amplification of disturbances is studied from an input-output point of view by analyzing the responses of the velocity components to spatio-temporal body forces. We utilize a componentwise frequency response analysis to reveal distinct resonant mechanisms for subcritical transition. In both Newtonian and viscoelastic fluids, the dominance of streamwise elongated flow patterns is observed which is in stark contrast to classical results from modal stability analysis. For streamwise independent perturbations, an explicit Reynolds number (Re) scaling of frequency responses from different forcing to different velocity components is developed, showing the same Re-dependence in Newtonian and viscoelastic fluids. We further demonstrate that elasticity promotes development of flow patterns with smaller time constants than in Newtonian fluids and that large amplification can be achieved even in weakly inertial/strongly elastic channel flows. The latter observation provides a possible route for transition to 'elastic turbulence' and may be exploited to enhance mixing in microfluidic devices. Finally, we discuss implication of our results to understanding and controlling transitional wall-bounded shear flows.

Mihailo Jovanovic received the Dipl. Ing. and M.S. degrees, both in mechanical engineering, from the University of Belgrade, Belgrade, Serbia, in 1995 and 1998, respectively, and the Ph.D. degree in mechanical engineering from the University of California, Santa Barbara, in 2004. He was a Visiting Researcher with the Department of Mechanics, the Royal Institute of Technology, Stockholm, Sweden, from September to December 2004. He joined the University of Minnesota, Minneapolis, as an Assistant Professor of Electrical and Computer Engineering in December 2004. His primary research interests are in modeling, analysis, and control of spatially distributed dynamical systems. Dr. Jovanovic is a member of IEEE, SIAM, and APS and an Associate Editor of the IEEE Control Systems Society Conference Editorial Board.
He received a CAREER Award from the National Science Foundation in 2007.