Mechanical Engineering Thesis Defense

Copper-based Nanostructures and Atomically Dispersed Metal Species for Heterogeneous Catalysis

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Abstract

The work herein examines optimal perturbations to channel flow and the stabilizingcontrol of perturbations through the Linearized Navier-Stokes (LNS) equationsand operator. In a three-dimensional (3D) turbulent channel flow, resolvent analysisinterprets nonlinear terms as a forcing term to the LNS system and througha singular value decomposition of the resolvent operator identifies the most amplifiedwall-normal shape of said forcing as well as the turbulent perturbation that actsas a response to the nonlinear forcing. Chebyshev integration and differentiationdiscretization techniques are both used in the construction of the LNS system for resolventanalysis, comparing relative error decay and condition number of matrices toinvert against matrix size N. While Chebyshev integration discretization techniquespresent accuracy advantages in some cases, for the discretization of the LNS operatorthey do not appear more suitable than differentiation-based discretization. Next, intwo-dimensional (2D) laminar flow the 2D LNS system was re-expressed as a partialintegral equation (PIE) to find stabilizing controllers for otherwise unstable perturbationsvia linear partial integral inequalities (LPIs). To this end, the PIETOOLSMatlab toolbox was used for the construction and manipulation of PIEs, as well asto perform the convex optimization required to test the feasibility of LPIs for systemstability and controller synthesis. Stabilizing controllers were successfully synthesizedand tested on an array of 2D LNS perturbation systems. The controllers do not accountfor the short-time behavior of the system, as large “spikes” were observed in thesimulations of the controlled systems that quickly decayed as the system stabilized.The use of resolvent analysis on the 3D turbulent channel provided a promising meansof identifying the form of most-amplified disturbance inputs to LNS systems, evenif more effective discretization techniques were not found. The synthesis of stabilizingcontrollers for the 2D LNS system, provided wavenumber and centerline-based Reynolds number, represents control schemes derived from the system dynamics directlyand do not rely on purely ad-hoc construction.

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Zoom Link: https://asu.zoom.us/j/82740873689