Control of the transition to turbulence in shear flows

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ABSTRACT

Despite over a century of intensive research, the problem of transition to turbulence in shear flows is not yet fully resolved. The traditional eigenvalue analysis that is based on the existence of a growing number of exponential temporal modes as the Reynolds number is increased fails to predict the transition to turbulence that is observed experimentally in such flows as the plane Poiseuille and plane Couette flows. In recent years an alternative theory has emerged that relies on the non normal nature of the linearized dynamical system that is associated with the flow. Even if all eigenvalues of such an operator lie well within the lower half of the complex plane, its non-normality may give rise to a significant amplification of initial small perturbations that may eventually lead to turbulence. Such behavior is well described by the pseudo-spectrum of the system. Choosing the total energy of the perturbation as a measure for the size of the disturbance, the physical characteristics of the optimally growing perturbations in plane Poiseuille flows are investigated as a function of the Reynolds number and the relevant wavelengths. The insight gained through that process is used together with the L_1 control method in order to design an optimal controller that minimizes the energy norm in short times, and thus leads to the delaying or suppression of the transition to turbulence. The L_1 control method is applied to a finite dimension state-space representation of the dynamical system. The transformation from the infinite-dimensional system to a finite dimensional one needs to be carried out carefully, such as not loosing essential features of the original system such as the pseudo-spectrum.