UNIVERSITY OF SOUTHAMPTON

ABSTRACT

FACULTY OF ENGINEERING AND APPLIED SCIENCE

SCHOOL OF ENGINEERING SCIENCES

Doctor of Philosophy

ROBUST CONTROL OF NON-LINEAR 2D AND LINEAR 3D DISTURBANCES IN CHANNEL FLOW BY SURFACE TRANSPIRATION

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The attenuation of perturbations in both periodic and non-periodic channel flow is attempted through wall-normal transpiration and point wall-shear-stress measurements. The transpiration is applied in both continuous harmonic form and a system based on discrete zero-net-mass-flux panel-pair form. For 2D flow it is demonstrated by means of a spectral Galerkin solver, that a simple classical controller with harmonic transpiration is capable of attenuating highly non-linear 2D perturbations. A multiple-input/multiple-output (MIMO) robust control scheme designed for the attenuation of perturbations in a non-periodic channel is applied to linear perturbations in the periodic setting. A certain set of linearly unstable modes in this periodic setting prove unstable for this control scheme. The significance of the last panel-pair in the scheme's failure in the presence of such modes is also demonstrated. In a non-periodic domain the MIMO robust control scheme is demonstrated to continue to attenuate simple 2D perturbations in the presence of certain prescribed actuator/sensor faults. The identification of which faults are detrimental to the control demonstrates the importance of upstream actuators and downstream sensors respectively. Such observations may be useful in the design of fault tolerant control schemes. An ad-hoc extension of the 2D MIMO controller is applied to a 3D flow. A simple perturbation is initialized in the flow by an upstream panel pair. It is demonstrated that this simple ad-hoc extension of a 2D controller successfully attenuates the wall-shear-stress perturbation. However, it is also demonstrated that this form of perturbation develops a velocity fluctuation away from the wall, such that simple wall-shear-stress measurements alone are unable to detect it. Alternative strategies are attempted to attenuate the inner part of the perturbation. These alternative methods use direct proportional control at each computational point to the measure wall-shear-stress in both streamwise and spanwise directions.