A Comparative Study of Turbulence in a Ramp-Up and a Ramp-Down Unsteady Flows

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Abstract – Direct Numerical Simulations of a turbulent channel flow subjected to a sudden change in pressure gradient are carried out to facilitate a direct comparative study of ramp-up and ramp-down flows. Various turbulent statistics are calculated and compared for the two flow excursions. Large differences are observed between the two flows at low Reynolds numbers. Unsteady wall shear stress in a ramp-up flow overshoots, and then undershoots the pseudo-steady value at the initial stage of excursion, whereas it does not deviate significantly from pseudo-steady values in the ramp-down flow. Furthermore, the intensities of turbulent fluctuation of the wall shear stress reduce at the beginning of the ramp-up flow showing an effect of “relaminarization” associated with flow acceleration. At this stage, the three components of the turbulent fluctuations exhibit distinctly different characteristics reflecting the anisotropic behavior of turbulence.

Nomenclature

δ : channel half width

uij, j=0,1 : friction velocity for the low(j=0) and high(j=1) flow rate of the ramps

subscript i=1,2,3 : 1, streamwise; 2, wall-normal; 3, spanwise directions

ui, i=1,2,3 : velocity non-dimensionalized by ut

ui′, i=1,2,3 : rms velocity perturbations non-dimensionalized by ut

ωi′, i=1,2,3 : rms vorticity perturbations non-dimensionalized by ut & H(=2δ)

u’v’ : shear stress non-dimensionalized by ut²

Un : local mean velocity non-dimensionalized by ut

Ub : bulk velocity non-dimensionalized by ut

Re = (2δ)μ / V : Reynolds number

ui* = u’ / Um, i=1,2,3 : normal turbulent stresses normalized by Um

(u’v’)* = u’v’ / Um² : shear turbulent stress normalized by Um²

1. Introduction

Unsteady turbulent flow has been of on-going interest to researchers for many years both because of its practical importance and its potential to provide additional insight into the