# A comparison of spatially and temporally accelerating flows

M. Falcone*, S. He*

We compare spatially accelerating turbulent boundary layers with temporally accelerating turbulent channel flow to understand the extent of the similarities between the response of turbulence in these flows. Spatial acceleration occurs in many engineering applications, including in high-lift aircraft systems where sudden changes in the skin and heat transfer coefficients can occur due to relaminarisation. Temporal acceleration is considered to have broad similarities to spatial acceleration[1] although there have been few previous attempts to compare them directly. We perform Direct Numerical Simulations of a spatially accelerating turbulent boundary layer undergoing relaminarisation and a temporally accelerating channel flow with matched acceleration parameter, $K = \frac{\nu}{U_\infty^2}\frac{\partial U_\infty}{\partial x}$. The simulations are performed using the Xcompact3D solver with the inflow conditions for the spatial acceleration generated using the recycling-rescaling method[2].

We show that the spatial acceleration case undergoes a transition process similar to that previously observed in temporal acceleration[3]. This transition process is characterised by an increase in the near-wall mean shear for $y^+ \lesssim 30$ due to the resistance to the acceleration provided by the wall. This mean shear amplifies the near-wall streaks through the lift-up effect without significantly affecting the transverse components. Eventually, these streaks break down forming turbulent spots, at which point, the transverse components begin to respond. Before the onset of transition, the transverse turbulent stresses exhibit some important differences. The spatial acceleration exhibits an absolute reduction of $\overline{v'v'}$ and $\overline{w'w'}$, consistent with previous studies of relaminarisation[4], whereas for temporal acceleration, these stresses remain at their values from before the acceleration. Analysis of the streamwise mean momentum balance indicates that the effect of flow contraction in spatial acceleration leads to much of the boundary layer accelerating more rapidly than the freestream leading to a reduction of the mean shear away from the wall ($y^+ \gtrsim 30$). In contrast, in temporal acceleration, this region accelerates without deformation. Some preliminary results of a modified temporal acceleration indicate that such changes in the mean shear can reduce the transverse stresses and intercomponent energy transfer similarly to that observed in strong spatial acceleration.

*Department of Mechanical Engineering, University of Sheffield, Sheffield, UK

[1] Greenblatt & Moss, *J. Fluid Mech.* **514**, 65 (2004).
[2] Lund et al., *J. Comp. Phys.* **140**, 233 (1998).
[3] He & Seddighi, *J. Fluid Mech.* **715**, 60 (2013).
[4] Piomelli & Yuan, *Phys. Fluids* **25**, 101304 (2013).