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Slow transition of the Osborne Reynolds pipe flow: A direct numerical simulation study. XIAOHUA WU, Royal Military College of Canada, PARVIZ MOIN, Center for Turbulence Research, Stanford University, RONALD J. ADRIAN, School of EMTE, Arizona State University, JON R. BALTZER, Los Alamos National Laboratory — Osborne Reynolds' pipe transition experiment marked the onset of fundamental turbulence research, yet the precise dynamics carrying the laminar state to fully-developed turbulence has been quite elusive. Our spatially-developing direct numerical simulation of this problem reveals interesting connections with theory and experiments. In particular, during transition the energy norms of localized, weakly finite inlet perturbations grow exponentially, rather than algebraically, with axial distance, in agreement with the edge-state based temporal results of Schneider et al (PRL, 034502, 2007). When inlet disturbance is the core region, helical vortex filaments evolve into large-scale reverse hairpin vortices. The interaction of these reverse hairpins among themselves or with the near-wall flow produces small-scale hairpin packets. When inlet disturbance is near the wall, optimally positioned quasi-spanwise structure is stretched into a Lambda vortex, which grows into a turbulent spot of concentrated small-scale hairpin vortices. Waves of hairpin-like structures were observed by Mullin (Ann. Rev. Fluid Mech., Vol.43, 2011) in their experiment with very weak blowing and suction. This vortex dynamics is broadly analogous to that in the boundary layer bypass transition and in the secondary instability and breakdown stage of natural transition. Further details of our simulation are reported in Wu et al (PNAS, 1509451112, 2015).

Xiaohua Wu
Royal Military College of Canada

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