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An active flow control theory of the vortex breakdown process ZVI RUSAK, JOSHUA GRANAT, Rensselaer Polytechnic Institute, SHIXIAO WANG, U. Auckland NZ — An active flow control theory of the vortex breakdown process in incompressible swirling flows in a finite-length, straight, circular pipe is developed. Flow injection distributed along the pipe wall is used as the controller. The flow is subjected to non-periodic inlet-outlet conditions. A long-wave asymptotic analysis results in a nonlinear model problem for the dynamics and control of both inviscid and high Reynolds number flows. The approach provides the bifurcation diagram of steady states and the stability characteristics of these states. In addition, an energy analysis of the controlled flow dynamics suggests a feedback control law which relates the flow injection to the evolving maximum radial velocity at the inlet. The feedback control cuts the natural feed forward mechanism of the breakdown process. Computed examples based on the full Euler and NS formulations at various swirl levels demonstrate the evolution to near-steady breakdown states when swirl is above a critical level. Moreover, applying the proposed feedback control law during flow evolution, shows for the first time the successful elimination of the breakdown states and flow stabilization on an almost columnar state for a wide range of swirl, up to 30 percent above critical.

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