Onset of Sustained Turbulence in Narrow-gap Taylor-Couette Flow

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ABSTRACT

Here we report a numerical study on the transition to sustained turbulence in counter-rotating Taylor-Couette flow in the narrow-gap limit, with the inner- and outer- radius ratio $\eta = 0.993$. At the onset of transition, a large-scale stripe pattern is observed to be a dynamical equilibrium state, independent of the type of initial perturbations. As Reynolds number Re is increased, the turbulent stripes contaminate the whole domain *via* splitting. Our observations also show that individual stripes will eventually decay and reliminarize. In this paper, the splitting and decay events of a single localized turbulent stripe are firstly inverstigated through the statistical method. Both events are shown to be memoryless, with an exponential probability distribution of the splitting time and lifetime, respectively. Then, inspired from the recent work done in pipe flow (see [1], [2], [5] and [6]), we associate the reason of the transition to sustained turbulence to the balance of the splitting and relaminarization events of turbulent stripes. By equalling the mean times of these two events, the threshold of the transition Re_c is determined to be 652 ± 4, which is in good agreement with the previously reported values [4]. Finally, the spatiotemporal diagram obtained in a large computational domain shows high similarity to the directed percolation model. In contrast to the extremely large timescales at criticality in pipe flow [1], the timescales in Couette flow ($\sim 10^3 d/U$) are four orders of magnitude smaller, which provides an unique opportunity to determine whether the onset of sustained turbulence falls into the universality class of directed percolation. Our study however also indicates that the critical Reynolds number depends on the system size and that the asymptotic value for an infinite system will be different.

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