186g Transitional Pathway to Turbulence Found in Elastic Fluids

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Multiple scenarios have been discovered by which laminar flow transitions to turbulence, based in part on experiments where transitions are caused by inertia or temperature, in Newtonian fluids. Here we show in non-Newtonian fluids a transition sequence that is due to elasticity from polymers, with negligible inertia. Multiple dynamic states are found linking the base flow to "elastic turbulence" in the flow between a rotating and stationary disk, including circular and spiral rolls. Also, a surprising progression from apparently "chaotic" flow to periodic flow and then to "elastic turbulence" is found. We name the modes we discover which link the stable base flow to "elastic turbulence", in experiments where either shear stress or shear rate is incrementally increased and then held at fixed values; the modes found following stable base flow are "Stationary Ring", "Competing Spirals", "Multi-Spiral Chaotic" and "Spiral Bursting" modes, followed then by "elastic turbulence". Each mode has a distinct rheological signature, and accompanying imaging of the secondary-flow field (simultaneous with rheological measurement) reveals kinematic structures including stationary and time-dependent rolls. The time-dependent changes in the secondary-flow structure can be related to the time-dependent viscosity in the case of several modes. We have also explored how polymer molecular weight in these solutions and gap-to-radius ratio affect (and possibly limit) the transitional pathway to "elastic turbulence".