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Transition to turbulence via material instabilities

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We present the Navier-Stokes (N-S) model enhanced with the viscous strength, which introduces material instabilities in addition to the kinematic ones.

We use the new model to simulate the pipe flow. In simulations we observe the spontaneous transition to turbulence around the critical Reynolds number of 2000. Such observation corresponds to the experimental data, while the classical N-S theory fails to predict any instability in the pipe flow[1] – Fig. 1. We argue that the transitional flow is a result of developing material instabilities.

We also use the enhanced N-S model to explain the drag reduction in the pipe flow via addition of a polymer solute. Simulations show that such an addition helps to suppress the chaotic flow yet does not allow making it fully laminar[2].

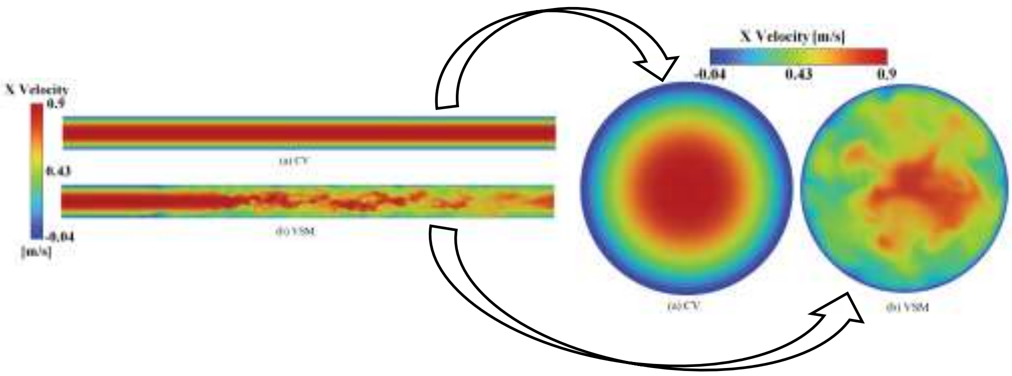

Figure 1: Left – longitudinal velocity profile for: (a) the classical Navier-Stokes model (CV) and (b) the modified Navier-Stokes model with viscous strength; Right – longitudinal velocity profile across the cross-section of the pipe at $L=10D$ from the inlet

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[1]Lahiri & Volokh, *Results in Engineering* **23**, 102535 (2024)

[2]Lahiri & Volokh, *Acta Mechanica* **234**, 4523–4533 (2023)