Proceedings of the Canadian Society for Mechanical Engineering International Congress
32nd Annual Conference of the Computational Fluid Dynamics Society of Canada
Canadian Society of Rheology Symposium
CSME/CFDSC/CSR 2025
May 25–28, 2025, Montral, Qubec, Canada

NUMBER

Localization Mechanisms in Mixing of Yield-Stress Fluids

Mohammad Reza Daneshvar Garmroodi[1]*, Ida Karimfazli[1]

[1]Mechanical, Industrial and Aerospace Engineering, Concordia University, Montreal, Canada
*Mohammadreza.daneshvargarmroodi@concordia.ca

DATE

Abstract

We investigate mixing mechanisms and regimes in yield-stress fluids, by simulating the stirring of an infinite, two-dimensional domain of a Bingham fluid. The fluid is stirred with a cylindrical stirrer whose center moves along a circular path at constant speed. The fluid is initially quiescent. The fluid filing the lower half on the domain is marked with a passive dye to model mixing dynamics. We first identify three mixing mechanism in stirring Newtonian fluids: stretching and folding of the interface along the path of the stirrer, diffusion across streamlines, and advection of the dye, with interface stretching due to vortex shedding. Investigating a wide range of laminar stirring flows and yield stresses, we characterize three key localization mechanisms: advection of vortices within a finite distance of the stirrer, vortex entrapment in the region of the stirrer and vortex shedding is completely suppressed at high yield stresses. From these mechanisms we identify three distinct mixing regimes in yield-stress fluids: (i) Regime SE, where shed vortices escape from the central region; (ii) Regime ST, where shed vortices remain trapped close to the stirrer; (iii) Regime NS where no shedding occurs. The critical criteria, marking transitions between different localization mechanisms, are characterized using the energy spectrum of the flow. By linking vortex dynamics to mixing localization, we draw analogies with bluff body dynamics and introduce effective Reynolds numbers to define transition criteria. The results establish a mechanistic framework for understanding and predicting mixing behaviors in yield-stress fluids, and suggest that the localization mechanisms and mixing regimes observed are archetypal for stirred-tank applications.

Keywords-component

Mixing; Yield-stress fluid; stirred tanks

Identify applicable sponsor/s here. (*sponsors)*