Proceedings of the 11th World Congress on Mechanical, Chemical, and Material Engineering (MCM'25)
Barcelona, Spain –Paris, France - August, 2025
Paper No. HTFF 207
DOI: 10.11159/htff25.207

Spreading Dynamics of a Soluble Surfactant in a Deep Layer of Shear-Thinning Fluid

Ruben Baños[1], Federico Méndez[2], Oscar Bautista[1], José Arcos[1]
[1] ESIME Azcapotzalco, Instituto Politécnico Nacional,
Avenida de las Granjas 682, Alcaldía Azcapotzalco,
Ciudad de México, 02250, CDMX, México
dbanosm@ipn.mx, obautista@ipn.mx, jarcos@ipn.mx
[2] Departamento de termofluidos, Facultad de Ingeniería,
Universidad Nacional Autónoma de México,
Ciudad Universitaria, Alcaldía Coyoacán,
Ciudad de México, 04510, CDMX, México.
fmendez@unam.mx

Extended Abstract

The Marangoni flow with a soluble and diffusive surfactant in a deep layer of non-Newtonian fluid is numerically analyzed. We solved the momentum equations considering inertial effects and the components of the stress tensor based on the Carreau model with the aid of the modified vorticity-stream function formulation. A tangential stress balance at the interface relates interfacial surface tension to surfactant concentration through a linear equation of state. The advection-diffusion equations for surface and bulk surfactant concentrations considering diffusive effects were solved using the one-dimensional Crank-Nicolson and Alternating-Direction-implicit (ADI) methods, respectively. Because of solubility, a mass exchange between the interface and the bulk fluid is driven by adsorption-desorption kinetics, resulting in a coupled system of nonlinear equations. The main parameters that control the temporal evolution of the initial surfactant distribution are the following: the fluid behavior index (n), the Carreau number (Cu), the Biot number (Bi), the solubility parameter (β), and the dimensionless surfactant depletion depth (α). Our findings indicate that the initial surfactant concentration reaches the homogeneous condition in a shorter time for shear-thinning fluids in comparison with Newtonian fluids. Due to the low viscosity of shear-thinning fluids, a greater amount of surfactant is transferred into the bulk fluid by solubility drastically reducing interfacial variations.

References

[1] Bickel and F. Detcheverry, Exact solutions for viscous marangoni spreading, Physical Review E 106, 045107 (2022).187
[2] Temprano-Coleto and H. A. Stone, On the self-similarity of unbounded viscous Marangoni flows, arXiv preprint arXiv:2401.13647 (2024).189
[3] O. Shardt, H. Masoud, and H. A. Stone, Oscillatory marangoni flows with inertia, J. Fluid Mech. 803, 94 (2016).191
[4] R. Baños, J. Arcos, O. Bautista, F. Méndez, and L. Martínez-Suástegui, Oscillatory Marangoni flow in a deep layer of a Carreau fluid, Phys. Fluids 35, 042115 (2023).193
[5] R. Baños, F. Méndez, O. Bautista, and J. Arcos, Spreading of a diffusive soluble surfactant in a deep layer with inertial effects, Physical Review E 111, 055501 (2025).