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Benchmark Solutions for Flows with Rheologically Complex Interfaces

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Abstract

Complex fluid–fluid interfaces determine for an outsized part the macroscopic material properties of foams and emulsions that appear in applications like food, materials processing and consumer care products. As a step towards predicting these properties, a 2D axisymmetric and a 3D finite element model are developed for simulating the dynamics of one Newtonian drop by a Newtonian matrix fluid with a rheologically complex sharp interface in between. Interfaces with constant interfacial surface tension and with viscous, elastic and viscoelastic extra interfacial stresses are considered. The model has been validated by means of the tactic of manufactured solutions and by comparison with results from other studies using different discretisation methods. Higher-order convergence in space and time is obtained, demonstrating correct implementation of our numerical methods. Benchmark solutions for a drop with a Kelvin–Voigt interface under simple shear flow are provided. Compared to a viscous interface, the drop deformation becomes smaller and therefore the drop becomes less oriented within the direction of flow if interfacial elasticity is added. Fluid–fluid interfaces play a key role within the processing and functioning of multicomponent materials. samples of such materials are emulsions, where fluid drops of 1 phase are dispersed into another fluid phase immiscibly. Dispersion are often useful for designing material structures to e.g. gain synergy of properties. Emulsions are partly for this reason utilized in a spread of applications like in food, paint, cosmetics, materials processing (e.g. polymer blends) and within the industry , but they also appear in nature and biology. The interfacial area to volume ratio in emulsions is comparatively large, since albeit the drops in e.g. polymer blends are small in size (about tens of); they're present in large quantities. Therefore, the interfacial properties determine for an outsized part the general macroscopic material behaviour. When applying flow to an emulsion, the structure is continuously developing through the consecutive and simultaneous deformation, break-up and coalescence of drops interacting with one another and therefore the surrounding fluid during a complex manner. Curvature changes of the interface are opposed or helped by interfacial surface tension between the phases. Surfactants that are often added as stabilisers to the mixture and adsorb at the interface, lower the interfacial surface tension to hamper or hinder coalescence Hence, surfactants are required to get stable emulsions, but they also further complicate the behaviour of the interface. Surfactant concentration gradients within the interface cause spatially varying Marangoni stresses. Surfactant transport within the interface or between the interface and therefore the bulk introduces non-trivial time scales. Besides, interactions within the interface thanks to a big microstructure cause extra and deviatoric interfacial stresses and possibly rheologically complex behaviour of the interface, These complex interfaces can behave intrinsically viscoelastic.

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