A FEM variational approach to the drop spreading over dry surfaces.

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Abstract

A numerical study on contact angle dynamics during spreading and recoil of droplets impacting orthogonally on various surfaces is presented. The Navier-Stokes equations are used where inertia, viscous, capillary and contact angle hysteresis phenomena act together to influence the contact motion. This numerical study is based on a finite element variational formulation of the problem and, since the problem is clearly singular, a limiting approach is discussed. The boundary singular condition is imposed as a penalty term and the problem is reformulated through an optimality system. The equation that relates the apparent contact angle and the contact line velocity is imposed as an external constraint. The evolution of the interface is solved over axisymmetric domains by using a new numerical surface tension representation and a new tracking marker technique, which conserves almost exactly the mass. The surface tension term is computed by using the fem test functions and therefore only the first derivative is required. This mathematical and numerical modeling of the wetting phenomena circumvents numerous difficulties due to the representation of surface tension, the non-integrable stress singularity at the moving contact line and the inability to describe in close form the velocity dependence of the dynamic contact line. In this work in order to see the capability of the numerical model the wetting properties of the target surfaces range from wettable to non-wettable and several numerical simulations with partial and complete rebound are investigated. A simple model for the apparent contact angle is used in order to provide an insight to the dynamic behavior of the apparent contact angle and its dependence on contact line velocity.