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A novel approach to surface tension modelling with the Finite Volume Particle Method

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Abstract

Surface tension plays a key role in many applications such as spraying, diffusion in porous media, birds drinking, etc. But simulation of surface tension is challenging because it involves a moving interface, topology changes, and triple lines where the dynamic contact angle is generally unknown. Surface tension is a macroscopic force resulting from microscopic interactions. Based on recent developments of the Finite Volume Particle Method, we propose a surface tension formulation directly derived from the macroscopic force for a single-phase configuration. Each particle represents a physical volume of fluid, and the free-surface is the union of the free-surfaces for each particle. Motion of these particles will cause a deformation of the free-surface and change its energy. Through analytical computation of these changes, the surface tension force is modelled by a particle-particle interaction that does not involve parameters other than a constant surface tension γ and the equilibrium contact angle at the triple line, θ_e. After a formal derivation of the force, we use it in various drop applications to validate its behaviour, both qualitatively and quantitatively. We also show that empirical dynamic contact angle models can advantageously be replaced by a physically meaningful surface roughness model. In this case, the roughness parameter has to be empirically evaluated.

Keywords: surface tension, wetting, FVPM, Finite Volume Particle Method, contact angle, surface roughness

1. Introduction

Surface tension is a pervasive phenomenon, both in nature and in industrial processes, for instance in spraying, tears of wine, water striders walking on water, cats or birds drinking, fracturing, and coffee making [1]. It has been the focus of numerous experimental and numerical studies aiming at modelling the phenomenon in order to better control surface tension related processes.

Most numerical models are based on a smooth color function whose gradient is used to compute the normal and curvature of the interface, from which a pressure force is calculated. This type of models can be applied to any mesh, immersed or not, and even to particle-based methods like Smooth Particle Hydrodynamics (SPH). These methods often encounter issues with momentum conservation, stability, and accurate curvature computation, while they handle triple lines by imposing a contact angle. An alternative that has been developed in the recent years, mostly for

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