Implementation of New Surface Tension Models for the Volume of Fluid Method

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Surface tension forces are relevant in numerous engineering applications, for example in bubble columns, fire sprinklers, ballistic flight phases of spacecrafts and many more. The main challenge is in discretizing this surface force on a volumetric field. Methods such as level-set, phase field and the volume of fluid method (VoF) require a special discretization in order to apply the surface tension forces on the volumetric field. Probably, the most well-known model for this challenge is the Continuum Surface Model (CSF) by Brackbill et al. [1] which smears the surface tension force over multiple cells:

$$F_{ST} = \sigma K(x)\delta(\mathrm{x})$$

by using a dirac delta function where $\delta(\mathrm{x}) = \nabla\alpha$ is the most common choice for a VoF method. The delta function needs to be discretized in such a way that exact balance between the pressure gradient and surface tension forces can be achieved [2]. This means that if a sphere initialized with the exact curvature no parasitic currents occur and the exact pressure jump can be observed. Luckily, interFoam uses this so called balance forced algorithm [2] and we observe parasitic currents in the order of machine precision if the curvature is exactly constant. However, the standard surface tension model of OpenFoam shows large errors in the curvature, K(x), computation causing the parasitic currents. In small scale application, these currents can be multiple magnitudes higher than the characteristic length scale resulting in unphysical velocities. If this standard OpenFOAM model is paired with the geometric VoF method, isoAdvector [3], the sharper representation of the interface causes even stronger parasitic currents. However, the availability of the new geometric VoF models [3] enables a more accurate interface description as shown in Scheufler and Roenby [4]and with it the possibility to implement more accurate surface tension models. Here, we want to present a library where multiple curvature models can be selected by a runtime selection mechanism and new models can easily be implemented. Currently four curvature models are available: the Brackbill model [1] (standard OpenFOAM model), the reconstruct distance function (RDF) [5], the height function method (HFM) [6] and parabolic fit (PF) [6]. The Brackbill [1]and the RDF model [5] work with the standard OpenFOAM algebraic interface compression VoF model and the isoAdvector method. The latter, HFM and PF, take advantage of the new geometric VoF method and are not compatible with the interface compression scheme. To test these models a circle is initialized and the parasitic velocities of the models are compared. We observe a reduction of the parasitic currents of roughly two magnitudes with the RDF model, one magnitude with the parabolic fit(PF) model and multiple magnitudes with the height function method compared to the current OpenFOAM model. A similar behavior is observed with the oscillation of a sin function, ellipsoid and the advection of a circle.

References

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