Improved numerical modelling of surface tension effects via a novel discretization of the Continuum Surface Force model

C.A.Batha, R. J. R. Williams, D. L. Youngs

AWE plc

http://awe.co.uk

Surface tension plays an important part in the dynamics of many interfacial and free surface flows, and is thus an important phenomenon in many industrial and engineering applications. Surface tension effects classically appear in the fluid equations as jump conditions at fluid interfaces where fluid properties vary discontinuously. The CSF model of Brackbill et al, [1], reformulates the discontinuous jump conditions, due to surface tension, at fluid interfaces by a smoothly varying volume force acting over the fluid interface. The method is extensively used, and has been extended to model compressible flows, but is known to generate un-physical "spurious currents" at fluid interfaces due to an imbalance in surface tension forces and associated pressure gradients, due to discretization errors in the static equation

$$\nabla p = \sigma \kappa \mathbf{n} \delta_s$$

By maintaining consistency with the discrete form of the jump condition at a steady interface, a novel numerical technique is presented in which the only potential source of "spurious currents" lies in curvature estimation errors.

Non linear side fraction functions of volume fractions, [3], are used to determine normal vectors of second order accuracy for interface reconstruction within a compressible volume of fluid formulation. Curvature estimates are then naturally determined using a discrete divergence operator. Accuracy of curvature estimation via the described method, relative to the height function approach, [2], is highlighted via a simple linear mode Rayleigh-Taylor instability problem. The method is then used to present results on surface tension effects in a variety of fluid mixing problems.

References

[1] J.U.Brackbill, D.B.Kothe, E.G.Puckett, *A continuum method for modelling surface tension*, J.Comp.Phys, **100**, 335-354 ,1992

[2] M. M. Francois, S. J. Cummins et al, *A balanced force algorithm for continuous and sharp interfacial surface tension models within a volume tracking framework*, J.Comp.Phys, **213**, 141-173, 2006

[3] D.L.Youngs, *Time dependent Multi-Material flow with large fluid distortion*, Numerical methods for fluid dynamics: Proceedings of a first conference 1982, 273-285, 1982