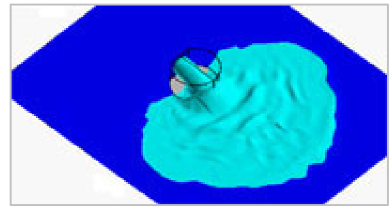
There are many problems in fluid dynamics that involve the analysis of two-phase free surface flows. These flows are characterized by fluids which have large disparities in density and their relative motion is the essence of the multi-phase phenomenon. Fluid surface tension plays a dominant role in the manner in which the fluids interact and largely determines the nature of the interface between fluids. Examples include droplets dynamics, tank sloshing, capillary motion, hydrodynamic stability and many others.



The Free Surface option provided in **CAESIM** predicts the motion of fluid interfaces based on the solution of a conservative transport equation for the fractional volume of fluid (VOF) defined as

$$F = \frac{V_{Fluid,II}}{V_{Fluid,II} + V_{Fluid,I}}$$

Where V represents the volume occupied by the fluid within the control volume under consideration. The function F obeys the equation

$$\frac{\partial F}{\partial t} + \frac{\partial}{\partial x_i}(uiF) = 0$$

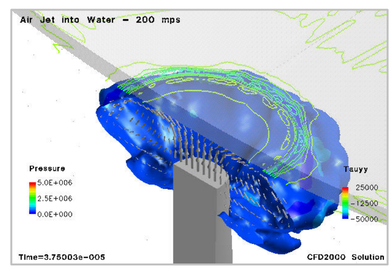
The solution to which provides information on the position and shape of the interface. The local mixture density is then computed by

$$\rho = \rho_{Fluid,II} F + \rho_{Fluid,I}(1 - F)$$

The momentum equation is also modified to contain an additional source terms relating to gravity, the curvature of the interface, and the fluid surface tension. When the equation for F is solved within a computational cell, changes in F within the cell are recast as fluxes of F across the cell faces. To preserve the sharp definition of the free surface, a high-order TVD scheme with damping is used.

CSF Model for Surface Tension force

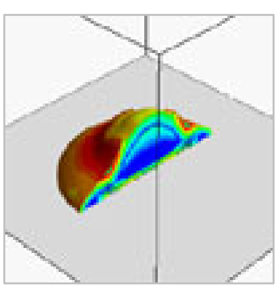
Surface tension at free surface is modeled in this work with localized volume force prescribed by the recent CSF (Continuum Surface Force) model [2]. In the CSF model, instead of a surface tensile force or a surface pressure boundary condition applied as a discontinuity, a volume force due to surface tension on fluid elements lying within a finite thickness transition region replaces the discontinuities.



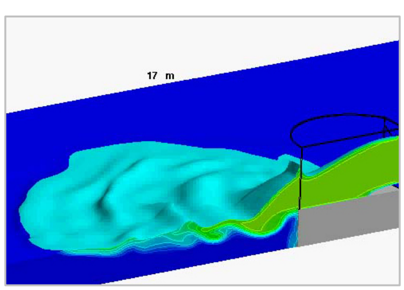
CSF formulation makes use of fact that numerical models of discontinuities in finite volume and finite difference schemes are really continuous transitions within which the fluid properties vary smoothly from one fluid to another. The volume force in the CSF model is calculated by taking first and second order spatial derivatives of the characteristic data. At each point within the free surface transition region, a cell-centered value F is defined which is proportional to the curvature K of the constant VOF surface at the point. Where, σ is the fluid surface tension coefficient, K is the free surface mean curvature, [F] is the difference of VOF data across the interface, and $\vec{n} = \nabla F$.

$$F_{sv} = \sigma\kappa \frac{\nabla F}{[F]}$$

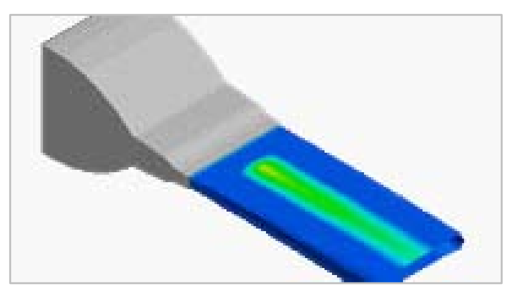
$$\kappa = \frac{1}{|\vec{n}|}\left[\left(\frac{\vec{n}}{|\vec{n}|} \cdot \nabla\right)|\vec{n}| - (\nabla \cdot \vec{n})\right]$$



Droplet Impact



LNG Spill on Water



Liquid Metal Nozzle Flow

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