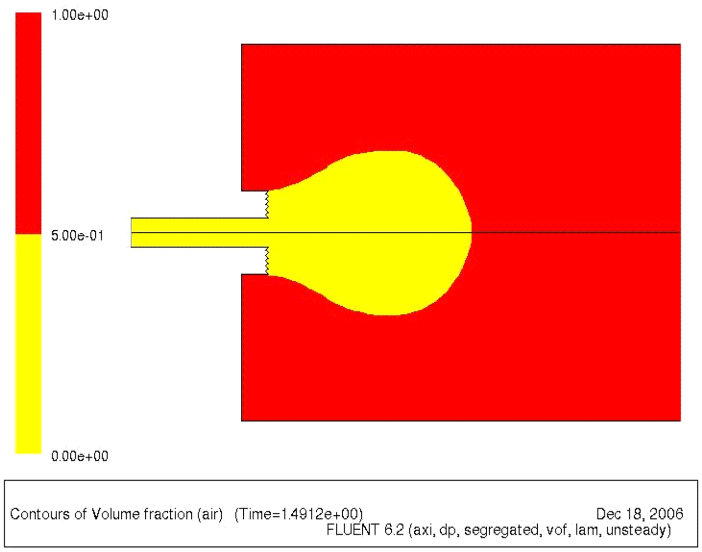
Liquid Drop Formation Theory and Simulation

The formation of a liquid drop on the end of a nozzle such as a faucet, pipe, or needle is a fascinating and complex problem. In fact, the problem is so incredibly complicated that often, researchers will make empirical relationships describing the phenomenon for a particular liquid of interest. This page will present introductory background, discuss a first order empirical solution, and introduce the concept of finite-volume numerical solutions to the problem.



Background

The basic variables driving drop formation are surface tension, viscosity, density, and nozzle geometry. Definitions for the latter items, in an engineering sense, are well known and can be readily referenced. Surface tension, however, will be discussed since it is the cardinal variable affecting the dynamics of drop formation (It should be noted that this is true for liquids with low viscosity. An exception would be a viscosity dominated system such as the pitch drop experiment.).

Surface tension- A term describing the effects of surface energy present due to incomplete bonding present at the surface of any material. In a liquid, surface tension is physically observed due to self-deformation that occurs in order to minimize surface area (thus reducing the surface energy of the material). As a result, the term 'surface tension' is generally used when referring to a liquid. Several instances where the effects of surface tension can be observed are water spiders, bubbles, dew, and capillary action. The units for surface tension are N/m.

First Order Empirical Approximation "The Tate Equation"

A good place to start when investigating a complicated problem such as drop formation is an empirical approximation. For fluids with relatively low viscosities, such as water, a basic relationship as been developed that describes the mass of a drop (density*volume) as a function of gravitational acceleration, surface tension, and nozzle geometry. This relationship is known as the Tate equation:

$$mg = 2\pi\lambda\cos(\alpha)$$

where $g = 9.81\ m/s^2$, λ = *surface tension (n/m)* ,

α = 90°-(angle between tube axis and horizontal)

m= mass of the drop (kg)

Although this relationship is sufficient for a general explanation of the problem, many significant variables are wholly neglected. For instance, viscosity is not present in this equation. Despite the simplicity of this basic empirical formula, it is amendable with correction factors (scalar terms that may vary as a function of conditions). The use of correction factors with the Tate equation can be seen in work such as that published by Harkins and Brown.

Finite Volume Numerical Solutions

Due to the inadequacies found with empirical relationships, the method of Finite Volume numerical solutions can be applied. By this method, fluid-fluid interactions can be described by coupling sets of conservation equations. A typical robust (accurate, stable, and consistent) method for fluid-fluid coupling is called the Volume of Fluid (VOF) method. Typical finite volume simulation environments capable of solving multiphase drop formation systems are OpenFoam and Fluent. If you have a specific question relating to drop formation, have an academic interest in pendant drop formation, or would like assistance in developing your own drop formation numerical model please contact Suprock Technologies.