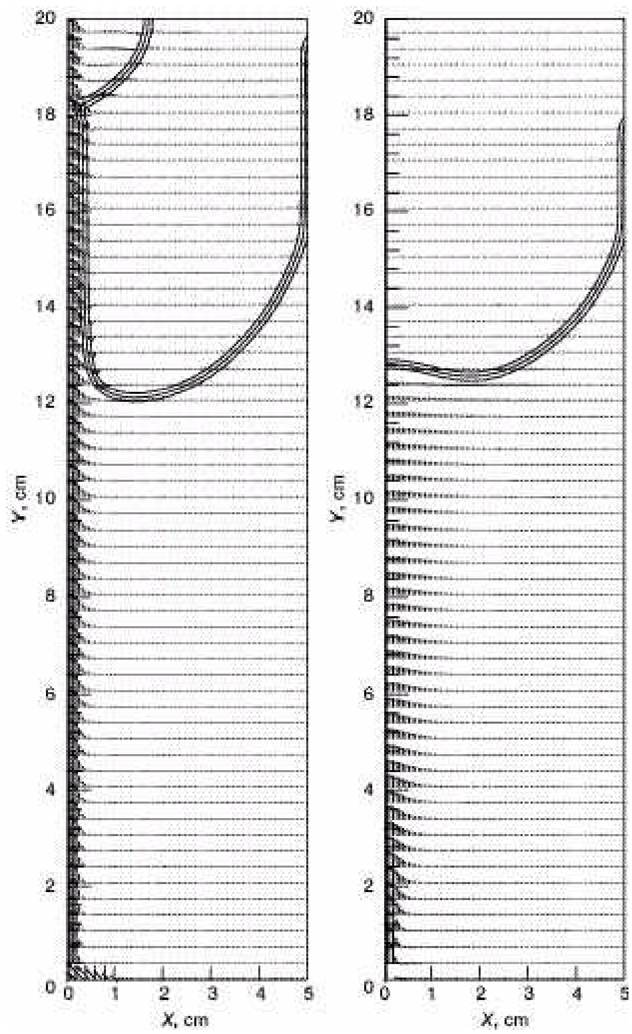
Influence of Turbulence on the Restraint of Liquid Jets by Surface Tension in Microgravity Investigated



Comparison of flow modeled laminarly and with turbulent viscosity added. Time, 3.10 sec; jet flow rate, 34 cm/sec; initial fill level, 11.9 cm at the centerline; reference vector, 50 cm/sec. Left: Laminar. Right: Turbulent.

Long description: Two computer models of a jet in microgravity. The laminar model shows a jet breaking through and striking the far end of the tank. The turbulent model shows the free surface restrain the jet.

Microgravity poses many challenges to the designer of spacecraft tanks. Chief among these are the lack of phase separation and the need to supply vapor-free liquid or liquid-free vapor to the spacecraft processes that require fluid. One of the principal problems of phase separation is the creation of liquid jets. A jet can be created by liquid filling, settling of the fluid to one end of the tank, or even closing a valve to stop the liquid flow. Anyone who has seen a fountain knows that jets occur in normal gravity also. However, in normal gravity, the gravity controls and restricts the jet flow. In microgravity, with gravity largely absent, surface tension forces must contain jets.

To model this phenomenon, a numerical method that tracks the fluid motion and the surface tension forces is required. Jacqmin (ref. 1) has developed a phase model that converts the discrete surface tension force into a barrier function that peaks at the free surface and decays rapidly away. Previous attempts at this formulation were criticized for smearing the interface. This can be overcome by sharpening the phase function, double gridding the fluid function, and using a higher order solution for the fluid function. The solution of this equation can be rewritten as two coupled Poisson equations that also include the velocity.

After the code was implemented in axisymmetric form and verified by several test cases at the NASA Glenn Research Center, the drop tower runs of Aydelott (ref. 2) were modeled. Work last year with a laminar model was found to overpredict Aydelott's results, except at the lowest Reynolds number conditions of 400. This year, a simple turbulence model was implemented by adding a turbulent viscosity based on the mixing-length hypothesis and empirical measurements of previous works. Predictions made after this change was implemented have been much closer to experimentally observed flow patterns and geyser heights. The figure shows two model runs. The first, without any turbulence correction, breaks through the free surface and strikes the far end of the tank. In the second, the turbulence spreads the jet momentum over more of the free surface, enabling the surface tension forces to turn the jet back into the bulk liquid. The model geyser height with the second model is 1.1 cm. This is quite close to the 1.5-cm geyser height measured by Aydelott.

References

1. Jacqmin, David: Calculation of Two-Phase Navier-Stokes Flows Using Phase-Field Modeling. J. Comput. Phys., vol. 155, 1999, pp. 96-127.

2. Aydelott, John C.: Modeling of Space Vehicle Propellant Mixing. NASA TP-2107, 1983.

Glenn contact: David J. Chato, 216-977-7488, David.J.Chato@grc.nasa.gov
Authors: David J. Chato

Headquarters program office: OAT
Programs/Projects: Space Launch Initiative, ASTP, Microgravity Science