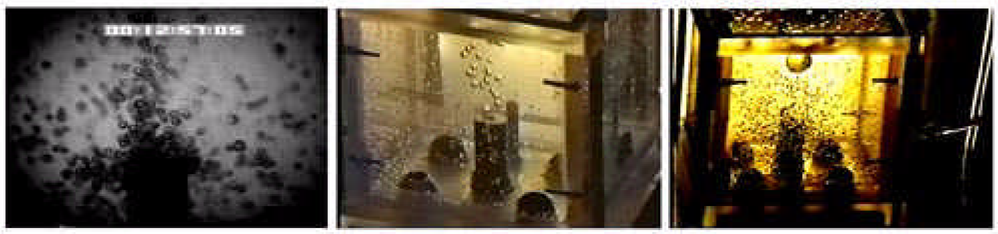
Bubbly Suspension Generated in Low Gravity

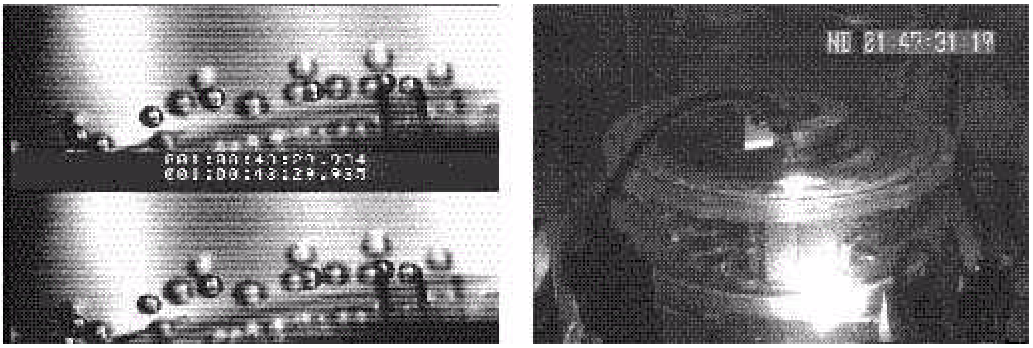
Bubbly suspensions are crucial for mass and heat transport processes on Earth and in space. These processes are relevant to pharmaceutical, chemical, nuclear, and petroleum industries on Earth. They are also relevant to life support, in situ resource utilization, and propulsion processes for long-duration space missions such as the Human Exploration and Development of Space program. Understanding the behavior of the suspension in low gravity is crucial because of factors such as bubble segregation, which could result in coalescence and affect heat and mass transport. Professors A. Sangani and D. Koch, principal investigators in the Microgravity Fluid Physics Program managed by the NASA Glenn Research Center at Lewis Field, are studying the physics of bubbly suspension. They plan to shear a bubbly suspension in a couette cell in microgravity to study bubble segregation and compare the bubble distribution in the couette gap with the one predicted by the suspension-averaged equations of motion. Prior to the Requirement Definition Review of this flight experiment, a technology for generating a bubbly suspension in microgravity has to be established, tested, and verified.

Generation of bubbly suspensions of uniform bubble diameter (standard deviation <10 percent) in space is a difficult task because bubbles do not detach as easily as on Earth. Under microgravity, the buoyancy force is not present to detach the bubbles as they are formed from nozzles. One way to detach the bubbles is to apply an external force on them. As suggested by Kim et al. (ref. 1), the drag force produced by a liquid flowing in a cross-flow or co-flow configuration with respect to the nozzle direction will detach the bubbles as they are being formed.



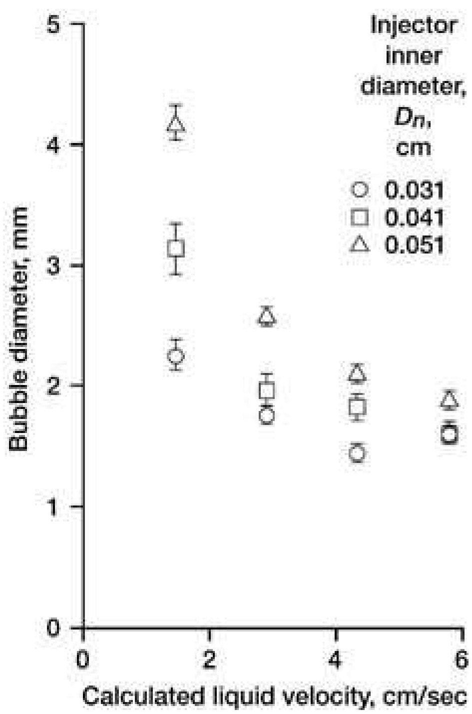
Spinning bubbler concept. Left: Two-dimensional side view. Center and right: Three-dimensional views.

Two flow loops were designed and built to test different concepts for creating a suspension in low gravity. In the first, bubbles were generated in a cubic test chamber, and in the second, in a couette cell. Both loops were totally contained and did not require any additional air or water during the low-gravity experiments. All bubbly-suspension-generation experiments were performed on NASA's DC–9 and KC–135 low-gravity aircraft. Two bubbler concepts were explored. The first was a spinning bubbler that uses the relative velocity of the nozzle spin to detach the bubbles. The preceding photographs show two- and three-dimensional views of this concept, which was tested in the first flow loop. The second was a stationary bubbler placed in a couette shear flow. The drag force created by the moving fluid causes the bubbles to detach. The following photographs show the stationary bubblers as indexed in the couette cell shear flow.



Stationary bubblers concept in a couette cell. Left: Two-dimensional top view. Right: Three-dimensional view.

The latest results of the stationary bubbler are shown in the graph, where the bubble diameter at detachment is plotted as a function of the local fluid velocity (ref. 2). As the liquid velocity is increased, the bubble diameter decreases because of the reduction in the time to detachment. This, in turn, is due to the higher drag force applied on the bubble. Similar trends were shown for the spinning bubbler. Both concepts are promising for generating uniform suspensions. Future efforts are planned to focus on the stationary bubbler concept integrated in the couette cell.



Latest results from the stationary bubbler concept. Bubble diameter is plotted as a function of the liquid velocity. The distance of the bubbler tip from the stationary inner *wall and into the couette gap is 0.25 cm; the gas flow rate is 16 cm^3/min.*

References

1. Kim, I.; Kamotani, Y.; and Ostrach, S.: Modeling Bubble and Drop Formation in Flowing Liquids in Microgravity. AIChEJ, vol. 40, no. 1, 1994, pp. 19–28.

2. Nahra, H.K.; and Hoffmann, M.: Generation of Bubbly Suspensions in Low Gravity. AIAA Paper 2000-0854, 38th AIAA Aerospace Sciences Meeting and Exhibit, Reno, NV, 2000

Glenn contacts: Henry K. Nahra, (216) 433–5385, Henry.K.Nahra@grc.nasa.gov; and Monica I. Hoffmann, (216) 433–6765, Monica.I.Hoffmann@grc.nasa.gov

Author: Henry K. Nahra

Headquarters program office: OLMSA

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