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Microgravity Experiments from Sub-orbital to Orbital Platforms (3)

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FLOW STABILITY EXPERIMENTS ON THE INTERNATIONAL SPACE STATION

Abstract

The subject of the presentation are numerical studies on capillary channel flow, based on results of the sounding rocket TEXUS experiments. The flow through a capillary channel is established by a gear pump at the outlet. The channel consists of glass plates with different geometries (parallel plates, groove, wedge). The meniscus of a compensation tube maintains a constant system pressure. Steady and dynamic pressure effects in the system force the surfaces to bend inwards.

A maximum flow rate is achieved when the free surface collapses and gas ingestion occurs at the outlet. This critical flow rate depends on the channel geometry, the flow regime and the liquid properties. The aim of the experiments is the determination of the free surface shape and to find the maximum flow rate.

In order to study the unsteady liquid loop behavior, a dimensionless one-dimensional model and a corresponding three-dimensional model were developed. The one-dimensional model is based on the unsteady Bernoulli equation, the unsteady continuity equation and geometrical conditions for the surface curvature and the flow cross-section.

In the case of steady flow at maximum flow rate, when the "choking" effect occurs, the surfaces collapse and cause gas ingestion into the channel. This effect is related to the Speed Index. At the critical flow rate the Speed Index reaches the value 1, in analogy to the Mach Number. Unsteady choking does not necessarily cause surface collapse. We show, that temporarily Speed Index values exceeding One may be achieved for a perfectly stable supercritical dynamic flow.

As a supercritical criterion for the dynamic free surface stability we define a Dynamic Index considering the local capillary pressure and the convective pressure, which is a function of the local velocity. The Dynamic Index is below One for stable flow while $D = 1$ indicates surface collapse. This studies lead to a stability diagram, which defines the limits of flow dynamics and the maximum unsteady flow rate.

To demonstrate the accuracy of the new theory preparations for experiments on the International Space Station ISS are in progress. Different geometries of the capillary channel design are implemented in the experimental payload which will be transported to the ISS with the next shuttle flight. The setup is situated in a Microgravity Scientific Glovebox and controlled from a Ground Station in Bremen (Germany). Different flow regimes can be established and the stability monitored online.