STABILITY OF LONG LIQUID COLUMNS

(WL-FPM-STACO)

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Abstract:

The aim is to measure the outer shape deformation of long liquid bridges under microgravity when subjected to mechanical disturbances, namely change of geometry, rotation and vibration. This configuration has, aside of its own relevance in fluidmechanics and interface science, a well-known application in materials processing, particularly in the floating zone technique of crystal growth in the semiconductor industry. As a spin-off of this research, this configuration has proved to be a unique accelerometer at very low frequencies.

Keywords: *Fluid physics, capillarity, microgravity, liquid bridge, stability, rotation.*

INTRODUCTION AND SCIENTIFIC OBJECTIVES

Research on that topic at this Institution started in 1975 and has concentrated on theoretical modelling and ground simulation of microgravity experiments using the neutral buoyancy technique. Several trials have already been performed aboard Spacelab-1 (1983), TEXUS-12 (1985), Spacelab-D1 (1985), TEXUS-18 (1988), TEXUS-23) (1989) and others are scheduled for SL-D-2 (not only this experiment but a collaboration on WL-AFPM-LICOR).

The aim is at gathering experimental data to validate several theoretical predictions on equilibrium shapes, stability limits and dynamics of stable and unstable bridges, in order to provide further guidance to more realistic and complex modeling.

EXPERIMENTAL PROCEDURE

The working configuration is a long (Length = 100 mm) and slender (Length/Diameter > 2) nearly-cylindrical liquid column spanning between two unequal discs, to the edges of which the liquid is anchored, as shown in Fig. 1. A low viscosity liquid, seeded with some tracers to visualize inner motion, is to be used (f.i. DMS-5 with Eccospheres). Once the column is established, several well-controlled mechanical disturbances are applied until the bridge becomes unstable: spinning of both discs to achieve solid-body rotation, disc separation, liquid removal, etc. The following steps are envisaged:

1. Preparation (arrange visualization, liquid supply and data-acquisition systems): 10 minutes
2. Establish a 100 mm long liquid bridge between discs of 40 mm and 35 mm ø: 4 minutes
3. Apply axial vibrations (frequency sweep at 90 s/Hz from 0.1 to 2 Hz): 3 minutes
4. Break by disc separation at constant liquid volume and merging back: 4 minutes
5. Break by liquid extraction at constant disc separation and merging back: 4 minutes
6. Break by isorotation (from 0 to 10 rpm at 9 s/rpm) and merging back: 4 minutes
7. Removal of the liquid, manual cleaning and change of discs: 5 minutes
8. Establish a 85 mm long liquid bridge between equal discs of 40 mm ø: 4 minutes
9. Break by disc separation at constant liquid volume and merging back: 4 minutes
10. Break by liquid extraction at constant disc separation and merging back: 4 minutes
11. Break by isorotation (from 0 to 20 rpm at 9 s/rpm): 4 minutes
12. Liquid recovery and cleaning: 10 minutes

Minimum crewtime needed: 60 minutes

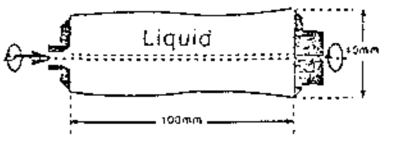

Fig. 1: Sketch of a long liquid bridge

The sequence from (8) to (19) can be seen in the volume-versus-slenderness stabilty diagram in Fig. 2 (for unequal discs it is quite similar).

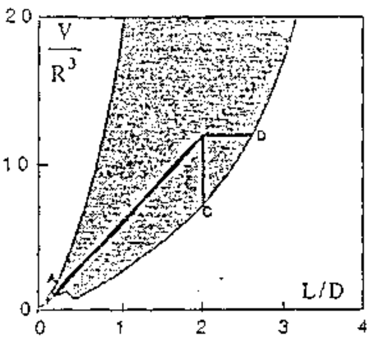

Fig. 2: Stability limits of a quiescent liquid bridge between equal discs in weightlessness.

Three special working discs (small metallic pieces as in SL-D1) are envisaged: two feeding discs, one of 35 and the other of 40 mm in diameter, and one opposite disc of 40 mm in diameter. The three discs are circular but the center of their working surface is offset 2 mm with respect to the axis of the AFPM chamber, to better analyse the isorotation trials. The discs must have enough heel to make them clearly visible in the video images. Their diameters are chosen as large as possible, but allowing to reach the cylindrical stability limit of $L_{max} = 2\pi R$, and the unequal discs are chosen in the ratio $H = 2\pi B$, where $H = (R_1 - R_2)/(R_1 + R_2)$ and B is the expected Bond number, $B = \rho g R^2 / \sigma = 0{,}01$.

The ESA-AFPM multiuser facility, similar to the *Fluid Physics Module (FPM) flown in SL-1 and SL-D1*, is to be used in SL-D-2. Once the bridge is established, diagnosis is based on the outer-shape recording and inner motion visualization by means of tracer particles. The operator monitors and executes the experiment interacting in real time, recording images through a video camera for later analysis, and sending performance data to ground for real time evaluation by the investigator. Experiment operation requires full attention of a crewman, and direct voice contact and video link with the investigator on ground is most important.

The possibility to have a portable microaccelerometer (MMA) attached to the *Front Plate* of the AFPM would be of high interest to this experiment (and it might be used as a calibrator for the MMA).

REFERENCES

[1] J.M. VEGA, J.M. PERALES: "Almost Cylindrical Isorotating Liquid Bridges for Small Bond Number", *in: ESA SP-191, ESA, Paris, p. 247/252 (1983)*

[2] I. MARTINEZ: "Results of an experiment on liquid column stability aboard Spacelab-1", *in Material Sciences under Microgravity, ESA SP-222, 1985*

[3] J. MESEGUER: "Stability of long liquid columns", *in Material Sciences under Microgravity, ESA SP-222, pp 297-300, 1984*

[4] J. MESEGUER: "Stability of slender, axisymmetric liquid bridges between unequal disks", *J. Crystal Growth 67, pp 141-143, 1984*

[5] J. MESEGUER, L.A. MAYO, J.C. LORENTE, A. FERNANDEZ: "Experiments with liquid bridges in simulated microgravity", *J. Crystal Growth 73, pp. 609-621, 1985*

[6] I. MARTINEZ AND A. SANZ. "Long liquid bridges aboard sounding rockets", *ESA Journal 9, 1985*

[7] I. MARTINEZ, J. MESEGUER: Floating Liquid Zones in Microgravity, *in: Scientific Results of the German Spacelab Mission D1, Sahm, P.R., Jansen, R. Keller, M.H. (Eds.), DLR, Köln, FRG, pp. 105/112 (1987)*

[8] J.M. PERALES, A. SANZ & D. RIVAS: "Eccentric Rotation of a Liquid Bridge", *Applied Microgravity Technology II, Issue 4, pp. 193-197, 1990*

[9] I. MARTINEZ AND A. SANZ: "Experiments with long liquid bridges under microgravity", *ESA SP-295, pp. 413-419, 1990*