LIQUID COLUMNS' RESONANCES

(WL-FPM-LICOR)

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Abstract:

It is intended to measure the resonance curves of liquid columns between coaxial circular disks and to test the corresponding theoretical models. The experiment will be performed in the Advanced Fluid Physics Module (AFPM). The supporting circular disks are vibrated with varying frequency. The response of the liquid column is observed by position and pressure sensors. It is intended to investigate two liquids differing in viscosity and surface tension and to use several liquid volumes and surface shapes. The resonance frequencies first are roughly determined by applying a frequency ramp and subsequently may be checked more accurately by frequency variation from hand.

INTRODUCTION AND THEORETICAL BASIS

It is intended to quantitatively investigate the oscillations of liquid columns and to test the corresponding theoretical models. Exact theoretical results exist for oscillations of liquid drops only. Investigations into liquid columns however offer the advantage, that they can be accurately exited with arbitrary frequency and amplitude by respective vibrations of the supporting disks. At the same time various sensors for measuring the response of the liquid column may be integrated into the supporting disks. The interest in liquid columns has been stimulated by the numerous applications to crystal growth by the floating-zone or travelling-heater techniques. Oscillations deteriorate the quality of the resulting crystals and therefore have to be carefully avoided.

The theory of oscillations of infinitely long liquid columns dates back to Lord Rayleigh (1879). The best known result is the instability of cylindrical columns, whose length L exceeds their circumference $2\pi R$. When the stability limit $L = 2\pi R$ is approached, a sinusoidal surface oscillation does not longer imply a surface enlargement, such that the restoring force of the surface tension vanishes. Fig. 1 depicts the resonance frequencies of infinitely long cylindrical liquid columns. The Ohnesorge number, the ratio of viscous damping to the driving surface tension

$$Oh = \rho\nu^2/\sigma R$$

has been plotted versus the reduced wavelength $\lambda/2\pi R$ of the oscillations. If damping is strong, no real oscillations of the column are possible. Any deformation of the surface is damped aperiodically (Bauer 1984, 1986). The full lines in Fig. 1 correspond to constant values of the real part $\omega' R^2/\nu$ of the resonance frequencies. The resonance frequencies clearly increase with decreasing Ohnesorge number, i.e. with increasing surface tension. The dashed lines correspond to constant values of viscous damping. Damping increases with decreasing wavelength.

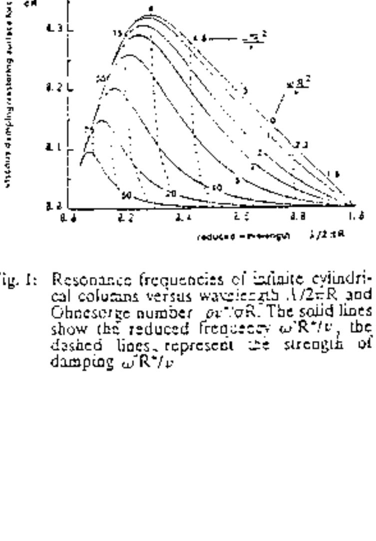

Fig. 1: Resonance frequencies of infinite cylindrical columns versus wavelength $\lambda/2\pi R$ and Ohnesorge number $\rho\nu^2/\sigma R$. The solid lines show the reduced frequency $\omega' R^2/\nu$, the dashed lines represent the strength of damping $\omega'' R^2/\nu$

If finite columns between supporting disks are considered, additional boundary conditions for the fluid flow at the disks have to be satisfied. The axial flow velocity has to meet the velocity of the supporting disks, whereas the radial flow at the disks vanishes. For correctly calculating the fluid flow, the different scientific teams contributing to the present experiment, suggested various models, the improvement of which is one of the objectives of the cooperation. Whenever possible, analytic methods are used. For the final evaluation numerical methods are envisaged. This is true in particular with respect to the influence of nonlinearities which may be important at high amplitudes. Fig. 2 shows the oscillation of a liquid column, which is being exited at the lower supporting disk. The Ohnesorge number is Oh = 1/16, the frequency is $\omega R^2/\nu = 4$. The phase difference between two successive plots equals $\pi/6$.

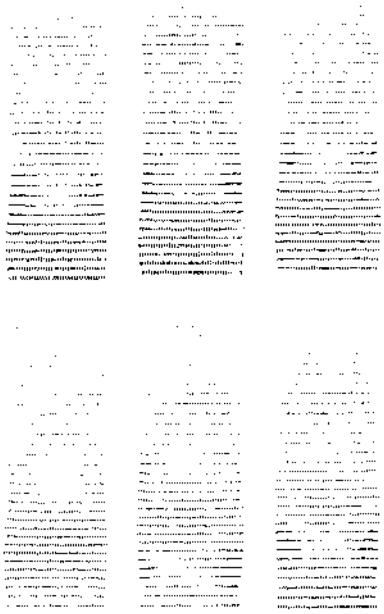

Fig. 2: Oscillation of a cylindrical liquid column, which is being exited at the lower supporting disk. The Ohnesorge number is Oh = 1/16, the frequency is $\omega R^2/\nu = 4$. The phase difference between two successive plots equals $\pi/6$

TERRESTRIAL REFERENCE EXPERIMENTS

Oscillations of liquid columns may be investigated in earth-bound experiments by using small dimensions of a few millimeters. These columns, however, still deviate from the cylindrical shape so that theoretical modelling is rather cumbersome. Another earth- bound method uses the Plateau technique, where the column of interest is immersed in a density-matched second fluid immiscible with the first one. In this way large columns can be generated. In theory, however, one has additionally to take account of the flow of the outer fluid. Nevertheless, both these earth-bound methods will be used for preparative investigations, the former by the Frankfurt team, the latter by the Madrid team.

EXPERIMENT PROCEDURE

The microgravity experiment is planned to run in the Advanced Fluid Physics Module (AFPM). Between two disks a liquid column of some centimeters in diameter will be established. Then one of the disks is vibrated with slowly increasing frequency and the response of the column is observed. The frequency range will include the lowest resonance frequencies as calculated from the theoretical models. For determining the fluid flow, the dynamic pressure acting on both the disks will be recorded. Since the pressure follows from the theoretical models immediately, it is most convenient for the testing purpose. At resonance the pressure amplitude has a maximum as compared to the amplitude of excitation. Moreover, the phase between excitation and pressure changes. For further terrestrial analysis the shape of the oscillating fluid column will be recorded by a video camera. It is intended to stepwise increase the length of the liquid column up to the stability limit in order to investigate the whole range of the aspect ratio. Oscillations with the same wavelength will be compared at different disk distances and numbers of nodes. The influence of viscosity will be examined by using various fluids such as water and silicon oil. The sensors for fluid pressure and disk position are integrated in an experiment submodule fitting into the AFPM. For data reduction the amplitude and phase of the pressure are evaluated already in the submodule. Only these parameters are transmitted to earth.

The results of the D-2 experiment will be used to check the range of validity of the various theoretical models, those already existing as well as those presently under preparation (Langbein 1991). Thus, reliable methods for predicting the effect of g-jitter on melt zones or solution zones during crystal growth become available.

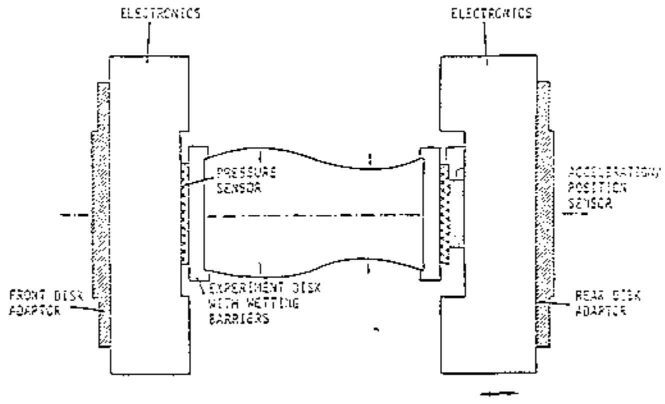

Fig. 3: Sketch of the submodule to be used in the AFPM

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