COMPARISON BETWEEN EXPERIMENTAL AND NUMERICAL ANALYSIS OF STABILITY OF LIQUID COLUMNS IN AN AXIAL GRAVITATIONAL FIELD ROTATING AROUND AN ECCENTRIC AXIS

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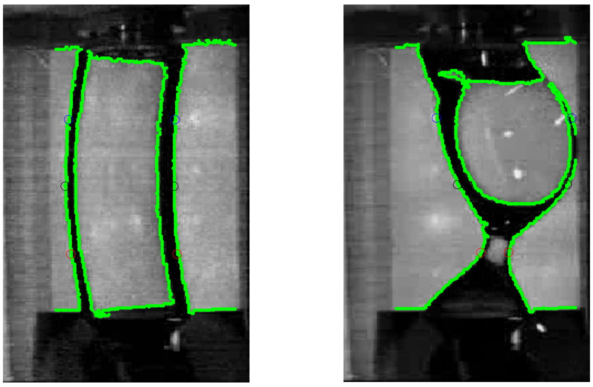
Summary An experiment in microgravity conditions aboard TEXUS-23 mission was performed in order to obtain the deformation up to breakage of a cylindrical liquid column in isorotation around an eccentric axis.
In previous works, breakage rotation speed was predicted by a numerical method. This method was validated by comparison with analytical and experimental results. However, the non-symmetric breakage of the liquid column observed in the experiment, was not explained by the combined effect of rotation and eccentricity.
In this work we use an extension of that algorithm including an axial gravitational field, so the combined effect of rotation, eccentricity and axial gravity is studied. Images captured from a video recorded during TEXUS-23 mission have been processed by an image analysis method to compare the equilibrium shapes from the experiment with the numerical ones. This analysis has allowed the understanding of the non-symmetric breakage of the liquid bridge in the experiment.

EXPERIMENTAL RESULTS

To date, some analytical and numerical studies [1]-[4], have been performed to understand and recover the results of an experiment in microgravity conditions aboard TEXUS-23 [5]. The experiment was performed in order to obtain the deformation up to breakage of a cylindrical liquid bridge supported between two circular-shaped disks in isorotation around an eccentric axis. Although breakage rotation speed was predicted by those numerical methods, the breakage shape of the liquid column observed in the experiment could not been explained.
Figure 1 shows the equilibrium shapes of the liquid bridge for two values of the rotation speed. In Figure 1(b), which corresponds to an equilibrium shape near the breakage, a non-symmetric shape is observed.



(a) (b)
Figure 1. Equilibrium shapes.

Images captured from the video have been processed by an image analysis method to compare the equilibrium shapes from the experiment with those obtained from numerical analysis. Figure 1 shows the boundaries of the liquid column detected and the limit points of those processed boundaries. These limit points are placed at ¼ (red points), ½ (black points) and ¾ (blue points) of the total length of the column.
Figure 2 shows the evolution of the distance to the axis of the disks (divided by the diameter of the disks) with the rotation speed. Line colors correspond to the limit points placed at ¼ (red line), ½ (black line) and ¾ (blue line). The non-symmetric evolution of the equilibrium shapes is clearly shown by the difference between lines corresponding to the limit points at ¼ and at ¾.
These non-symmetric shapes cannot been explained by the combined effect of rotation and eccentricity because, for the slenderness of the liquid bridge considered, only one type of instability, C-mode, appears, which leads to symmetric equilibrium shapes. So, another effect, which produces this non-symmetry, must be considered: the gravitational field. Although the experiment has been performed in microgravity conditions, the effect of the gravity is crucial to explain the non-symmetric shapes. Specifically, the axial component of the gravitational field is the important one, because the lateral component produces also symmetric equilibrium shapes (C-mode).

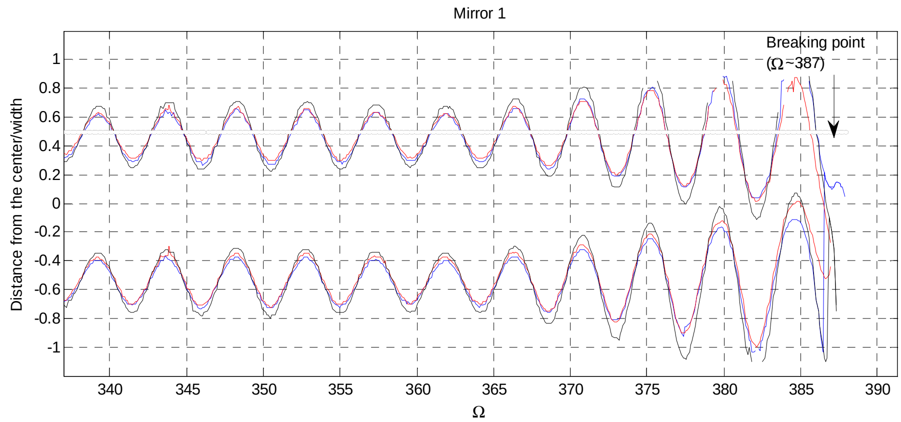


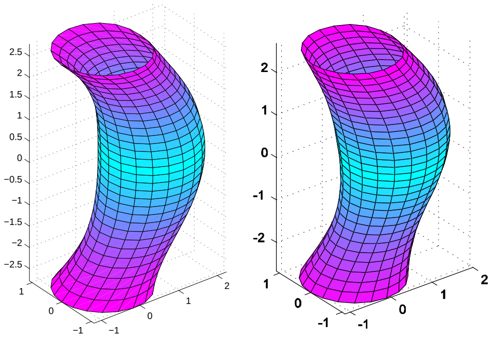
Figure 2. Evolution of the distance from the limit points to the axis of the disks (divided by the diameter of the disks) with the rotation speed.

SOME RESULTS

In a previous work [6], the combined effect of an axial gravitational field and an offset between the rotation axis and the axis of the supporting disks (eccentricity) on the stability of the liquid bridge was considered. Before that work, numerical and analytical studies have been done only for the cases (i) axial gravity and no eccentricity [1], [2] and (ii) eccentricity and no gravity [3], [4].

In [6] the evolution of the stability threshold for different values of the parameters was analyzed. The slenderness of the liquid bridge considered in the experiment is Λ =2.5 and the dimensionless eccentricity is e=0,067. For these values, the effect of low values of axial gravity (that is, low Bond number. B_a) in the stability threshold is very little. This explains why previous works, which do not consider gravity effects, could predict breakage rotation speed, but they could not recover the non-symmetric equilibrium shapes, as Figure 3 shows.

In this work a comparison between the experimental results shown in Figure 2 and the numerical ones, obtained from the analysis in [6], has been performed. This analysis has allowed the final understanding of the non-symmetric breakage of the liquid bridge in the experiment and the validation of the numerical method.



(a) (b)

Figure 3. Equilibrium shape for Λ =2.5, e=0,067 and (a) B_a =0, (b) B_a =10^{-3}.

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