Unexpected dynamic behavior of a mass lifted by near-field acoustic levitation

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It is possible to levitate a mass by vibrating a flat disk located under the mass. The acoustic levitation is particularly useful when the adherence forces are not negligible in comparison to the weight of the mass. In this paper, we studied experimentally and theoretically the dynamic behavior of a levitating mass for different magnitudes and frequencies of vibration of the flat disk. The vibration magnitude of the mass appears to independent on the disk vibration amplitude.

Keywords: Tribology, Squeeze film levitation, Gas lubrication

1. Introduction

Salbu [1] was probably the first to study the phenomenon of acoustic levitation in 1964. This pioneering work was followed by many papers. Brunetière et al [2] experimentally studied the phenomenon while varying the magnitude and frequency of vibration of the flat disk. The low precision of the sensors did not permit to reach accurate results on the vibrations amplitude. New optical sensors allow the authors to observe unusual dynamic behavior that was confirmed by the analytical and numerical solutions.

2. Methods

The configuration of the problem is presented in figure 1 and the main data are given in Table 1.

Table 1: data

Frequency	500 - 4000 Hz
magnitude *e*	0 - 3 µm
mass	17,76 g
Mass radius	15 mm

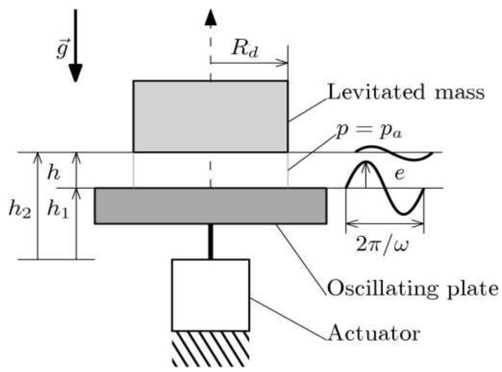

Figure 1: Configuration of the problem.

2.1. Analytical solution

Using several simplifying assumptions, it is possible to show that the vibration amplitude of the mass is:

$$a = \frac{g}{\omega^2\sqrt{L}}\left(1 + \frac{L}{2}\right) \qquad (1)$$

Where L is the load parameter:

$$L = \frac{mg}{\pi R_d^2 p_a} \qquad (2)$$

2.2. Numerical model

A numerical tool based on the Reynolds equation and the Newton's law allows to calculate the pressure in the air film and the vertical position of the levitated mass.

2.3. Results

Figure 2 presents the standard deviation of the mass vibration obtained at a frequency of 3500 Hz as a function of the amplitude *e* of the disk vibration.

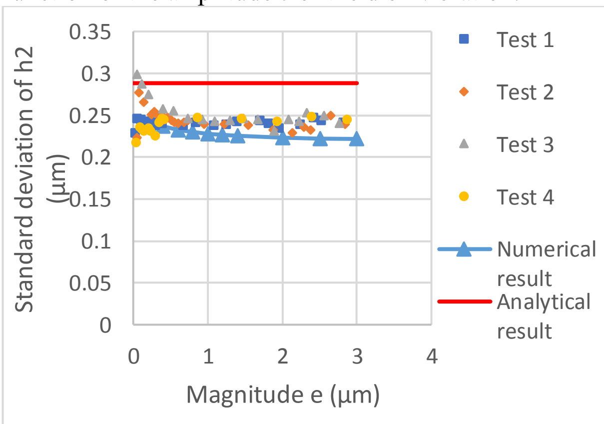

Figure 2: Standard deviation of the levitated mass position h_2 as a function of the vibration magnitude *e* of the flat disk.

3. Discussion

Figure 2 shows that the magnitude of vibration of the mass does not depend of the magnitude *e* of vibration of the flat disk for values of *e* between 0.3 and 3 µm. For this range, the average film thickness varies between 10 to 40 µm. It leads to a film stiffness and damping adaption maintaining thus the vibration amplitude of the mass. This unusual behavior is experimentally, numerically and analytically obtained. For very small values of *e*, deviations, probably due to the occurrence of condensation drops between the solids, were observed. For these cases, the air gap was lower than 10 µm.

4. References

[1] Salbu, E, "Compressible Squeeze Films and Squeeze Bearings," J. of Basic Eng., 86, 1964, pp. 355-364.

[2] Brunetière, N., Blouin, A., and Kastane, G., "Conditions of lift-off and film thickness in squeeze film levitation," J. of Tribol., 140, 2018, 031705.