Plate Actuator Vibration Modes for Levitation

A. Almurshedi[1)], M. Atherton[1)*], C. Mares[1)], T. Stolarski[1)], B. Wei[2)], Y. Wang[2)]

[1)]College of Engineering, Design and Physical Sciences, Brunel University London, UK
[2)]School of Mechanical Engineering, Beihang University, Bejing, PRC
*Corresponding author:Mark.Atherton@brunel.ac.uk

The design of an aluminium or steel plate of various thicknesses for achieving levitation of a small aluminum disk is investigated by simulation using ANSYS. Each plate design is excited by an arrangement of four hard piezoelectric actuators driven with an AC voltage, which produces a centre displacement for generating a squeeze-film in the gap between the vibrating plate and the disk. Physical experiments show levitation conditions for one of the designs.

Keywords: tribology, piezoelectric, ANSYS, squeeze-film

1. Introduction

The applied loading, geometrical configuration and relevant material properties of a plate are considered the important parameters that govern structural deformation and natural frequency of vibration and, accordingly, the squeeze film thickness and levitation characteristics. The squeeze-film separating force will be produced in the air gap between an object to be levitated and the plate when subjected to oscillatory relative motion at an appropriate high frequency [1]. Piezoelectric actuators bonded to a plate that is fixed at its ends (Figure 1) and excited with an alternating voltage will create the necessary plate oscillatory motion that produces the squeeze film under an object.

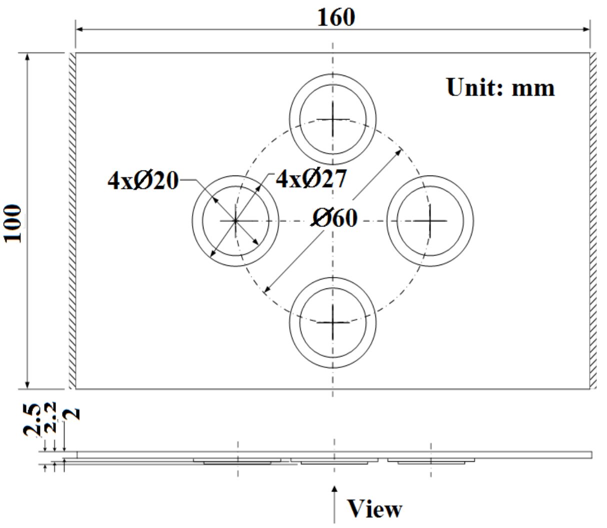

Fig.1: Plate with four piezoelectric exciters

2. Method

As the natural frequency of a plate can be controlled by its mechanical properties particularly the Young modulus and the density, then two materials, stainless steel and aluminium, are investigated plus thickness using simulation to assess their influences on the vibration amplitude of the plate and, indirectly, the squeeze film thickness and levitation [2, 3].The forced harmonic performance for six different plate designs are investigated through simulation in ANSYS15 for a frequency range of 0-40 kHz in order to identify a more effective plate design for levitation [1, 2]. Three thicknesses (1, 2 and 3 mm) are explored for both aluminium and stainless steel plates. All the plate designs are fixed at the ends and have four PZT4 bonded underneath the plate, which are simultaneously driven by a 75 V AC supply.

A physical prototype based on an aluminium plate (160mm x 100mm x 1.9mm) and four hard piezoelectric actuators type PZT4 has been built to verify the feasibility of zero-friction conveying of small items. The levitating behaviour is observed using a scanning Laser Doppler Vibrometer (Polytec PSV 500) across a frequency range of 0-20 kHz (Figure 4) in order to find the most effective plate vibration frequencies and their corresponding modal shapes. A laser displacement sensor (ILD 2300 Micro-Epsilon) is used to measure the levitation distance of the disk which is placed over the aluminium vibrating plate (Figure 5) and it is used to measure the center point deformations of the top surface of the aluminium vibrating plate across a frequency range of 0-40 kHz.

3. Results

The simulation results for the aluminium plate designs with various thicknesses (Figure 2) show that 2mm is the preferred thickness but with high deformation occurring at an audible frequency around 7.2 kHz and 11 kHz. However, for a stainless steel plate (Figure 3) the preferred thickness is 3mm and maximum deformation occurs around 24 kHz, which is beyond audible frequencies.

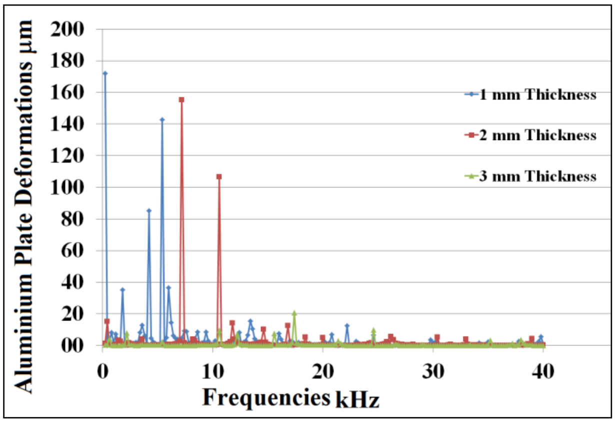

Fig. 2: Simulation results for aluminium plates of various thicknesses.

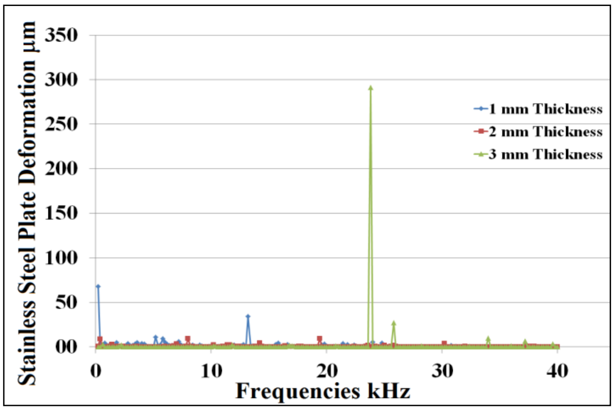

Fig. 3: Simulation results for stainless steel plates of various thicknesses

Figure 4 compares the harmonic shapes comparison between scanning Laser Doppler Vibrometer measurements (Polytec) and ANSYS simulation results for an aluminium plate of size 160mm x 100mm x 1.9mm, showing good agreement.

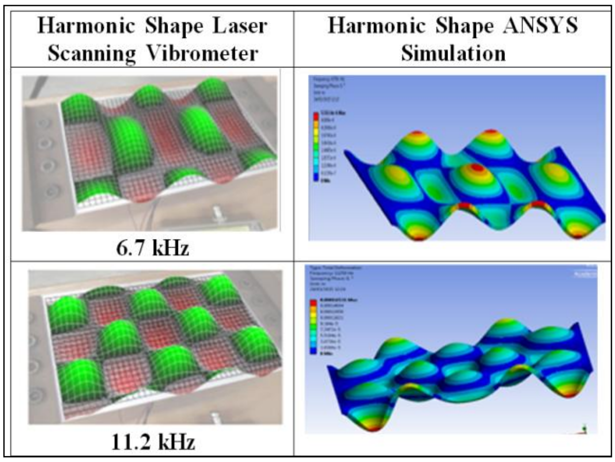

Fig. 4: Harmonic shapes comparison between Laser Scanning Vibrometer measurement and ANSYS simulation.

However, using a laser displacement sensor (ILD 2300 Micro - Epsilon), the effective frequencies for maximum levitation height of a 5g aluminium disk (Figure 5) floating on the aluminium plate are not easily compared with the simulation results of Figure 2. This may be due to the squeeze film being unstable.

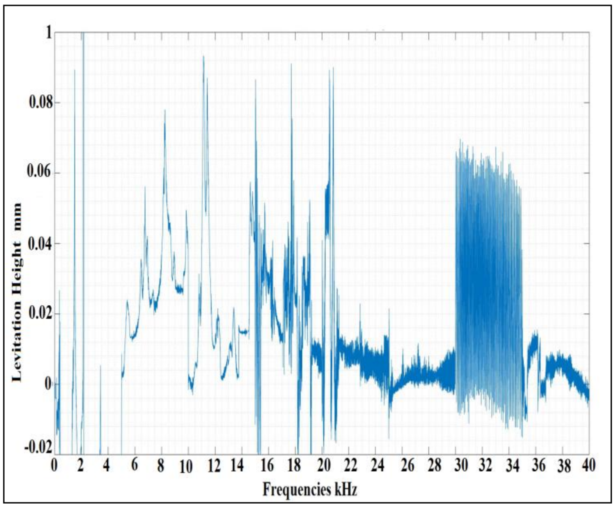

Fig. 5: Laser displacement sensor measurement of levitation height for 5g aluminium disk.

4. Conclusion

Squeeze-film levitation occurs at audible frequencies for the aluminium plate sizes investigated but simulation results indicate that a stainless steel plate design will produce effective levitation at much higher frequencies.

5. References

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