Acoustic Levitation

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1 Introduction

Imagine you could let something float like the candles in the magical world of “Harry Potter”. It may seem unrealistic, but physics makes levitation possible. Small objects can be levitated by a standing sound field.

2 Theory

In the standing sound field there are axial and radial forces, which hold the levitated object in place at the pressure nodes. The axial force results from pressure differences in the sound field. Due to these pressure conditions there are also potential energy differences. Because an object strains to the location with the lowest energy (at the pressure nodes) there are axial forces. The axial levitation force can be determined by the following equation [1]:

$$F_Z = \frac{5}{8} k \rho_0 {v_{max}}^2 V_p f(x) sin(2k\Delta z)$$

In this equation, ρ_0 is the density of the air and k is the wave number with $k = \frac{2\pi}{\lambda}$. Δz is the deflection from a pressure node and V_p is the volume of the probe. The maximum velocity v_{max} can be determined by $v_{max} = 10^{\frac{L_{p[dB]}}{20}} \sqrt{2} \cdot v_{ref}$ with $v_{ref} = 5 \cdot 10^{-8} \frac{m}{s}$ and the sound pressure level L_p in dB, and $f(x)$ is the geometry factor of the probe.

3 Research Methods

We constructed a setup to levitate small objects.

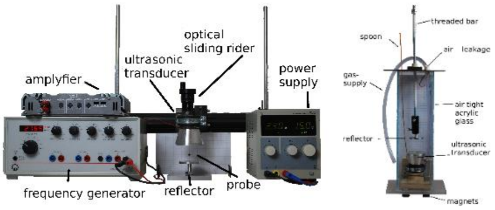

Fig. 1: Experimental setup

This setup contained an ultrasonic speaker and a reflector. The speaker was connected to a frequency generator with an amplifier and was fastened to an optical sliding rider to enable fine tuning of the resonator length (the distance from the reflector to the speaker). This distance is important because a standing wave can only develop if the resonator length is $L = n \cdot \frac{\lambda}{2}$ (with $n = 1,2, ...$) For all experiments a frequency of 27.65 kHz was used.

By taking photos of the levitated objects (e.g. styrofoam beads) it was possible to evaluate the experiments with the video analysis program *Tracker*. We also constructed a setup out of acrylic glass for experiments in various gases (Fig. 1, right).

4 Results

It was possible to visualize a standing wave by holding a soap bubble into the resonator (Fig. 2).

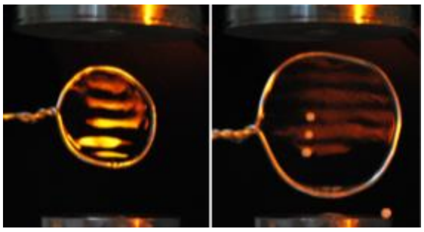

Fig. 2: left: soap bubble in the standing sound field; right: styrofoam beads in the soap bubble

By putting styrofoam beads in to the soap bubble, it was possible to determine the exact position where objects levitate in the standing sound field. The probes levitated at different resonator lengths about 1 mm underneath the pressure node. This experimental result corresponded with theoretical data. It was also possible to levitate beads in different gases. The theoretical and experimental resonator lengths are shown in Fig. 3, left.

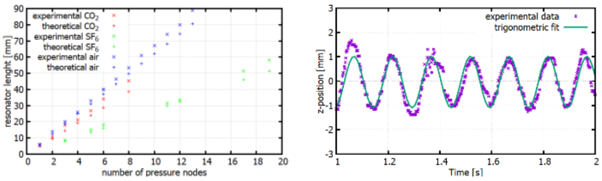

Fig. 3: left: Comparison of different resonator lengths in various gases with theoretical data; right: oscillation of a styrofoam bead

During the experiments we noticed that levitated beads oscillate when nudged. By using a high-speed camera and the video analysis program *Tracker* it was possible to compare these oscillations (Fig.3, right) to the theoretically expected oscillations. The frequency of the oscillation was about 7 Hz.

5 Conclusion

Small objects can levitate underneath the pressure nodes of ultrasonic standing waves. They are held up by levitation forces, which are also responsible for the oscillation of the levitated object.

6 References

[1] R. Tuckermann et al. “Schwebende Tröpfchen“ Physik in unserer Zeit, Vol. 32, edition 2, p. 69-75, March 2001

[2] V. Klein, Universität Stuttgart. Akustische Levitation von Ferrofluiden, 20. September 2010