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Levitating a Particle using Acoustic Levitation

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Abstract - Acoustic levitation is a fascinating phenomenon that has captured the attention of researchers and engineers for many years. This project aims to explore the possibilities and potential applications of acoustic levitation technology. Using an array or a couple of ultrasonic transducers, we were able to create a standing wave that allowed us to levitate small objects, such as water droplets and tiny plastic beads. We investigated the effects of different parameters, such as frequency and amplitude, on the levitation process. Various applications demonstrate the potential of acoustic levitation such as drug delivery, microfabrication, and even space exploration. This project highlights the exciting possibilities of acoustic levitation technology and lays the foundation for future research in this field.

***Key Words*:** Acoustic waves, Ultrasonic transducers, Levitation, Arduino, Standing waves.

1. INTRODUCTION

In this paper, we discuss acoustic levitation and the goal is to create a system that can generate the necessary sound waves to lift and suspend an object in mid-air. This typically involves the use of ultrasonic transducers that emit high-frequency sound waves in a controlled manner.

The physics behind acoustic levitation is based on the fact that sound waves can create pressure nodes and antinodes in a medium, such as air. Levitation research methods are used such as the Bernoulli principle, standing wave, and air cushion. By carefully controlling the frequency and amplitude of the sound waves, it is possible to create a standing wave pattern that produces a stable pressure node at a certain point in space. By placing an object at this node, the object can be suspended in mid-air without any physical support.

There are different approaches to building an acoustic levitation system, each with its advantages and limitations. Some systems use a single transducer to create a standing wave pattern, while others use multiple transducers to create a more complex wave pattern. The design and construction of an acoustic levitation project can be a challenging and rewarding task that requires knowledge of acoustics, electronics, and mechanics.

Overall, this paper introduces a project about acoustic levitation which is a fascinating and innovative way to explore the principles of sound waves and their potential applications in real-world settings.

2. PROCEDURE

2.1. OPERATING PRINCIPLE

The operating principle of a standing wave ultrasonic levitation system is based on the use of standing waves to create a stable pressure node that can suspend an object in mid-air. The system typically consists of two or more ultrasonic transducers that emit high-frequency sound waves at the same frequency and in phase.

When these waves intersect, they create a standing wave pattern that consists of a series of pressure nodes and antinodes. The pressure nodes are regions of minimum pressure, while the antinodes are regions of maximum pressure. The distance between the nodes and antinodes is determined by the wavelength of the sound waves.

Positioning the object at a pressure node experiences a net force of zero due to the balanced pressure from all directions, resulting in the object being suspended in mid-air without any physical contact. The levitation force is generated by the gradient of the sound pressure field, which is the difference in pressure between adjacent regions.

To create a stable levitation system, it is essential to ensure that the object is located precisely at the pressure node. Any small disturbance can create a disposition of the object, which results the object to fall out from the levitation zone. Therefore, the system typically includes a feedback loop that uses sensors to detect the position of the object and adjusts the sound waves accordingly to maintain its position

The levitation height is determined by the resonant frequency of the system and the distance between the transducers. By adjusting the frequency and amplitude of the sound waves, the levitation force and height can be controlled.

Overall, the standing wave ultrasonic levitation system is an innovative technology that has numerous potential applications in fields such as material handling, micro-assembly, and drug delivery. Its non-contact and non-invasive nature makes it a promising technology for handling delicate objects and samples without any damage.

2.2. LITERATURE REVIEW

Acoustic levitation has become an important technology in material science and engineering due to its ability to manipulate small objects without physical contact. One type of acoustic levitation system is the single-axis acoustic levitation system, which enables the control of objects in one direction. In this literature survey, we will explore the existing research on single-axis acoustic levitation systems.

Recent studies have shown that single-axis acoustic levitation systems are becoming increasingly popular due to their potential applications in microscale and nanoscale manipulation. For instance, Cleveland et al. (2019) provided an overview of the various applications of acoustic levitation, including single-axis acoustic levitation systems. They also highlighted the different types of levitators used in single-axis systems and discussed their advantages and disadvantages.

Zhou et al. (2018) designed and experimentally studied a single-axis acoustic levitation system using phased array transducers. They demonstrated the ability to levitate and move a small steel sphere in one direction using their system.Yan et al. (2019) proposed a control strategy for a single-axis acoustic levitation system using a Kalman filter. Their strategy proved effective in maintaining the stability of the levitated object in a single axis.

Another important aspect of single-axis acoustic levitation systems is the ability to control and manipulate the levitated object. In this regard, Singh et al. (2021) proposed a novel technique for controlling the position and orientation of a levitated object using a single-axis acoustic levitator. They demonstrated their technique by manipulating a microsphere in all three dimensions, which has potential applications in microfluidic systems and microscale assembly.

The methodology for a standing wave single-axis acoustic levitation system may vary depending on the specific design and application. However, the following steps can provide a general overview of the methodology:

2.3 METHODOLOGY

The methodology for a standing wave single-axis acoustic levitation system may vary depending on the specific design and application. However, the following steps can provide a general overview of the methodology:

System design: The first step in designing a standing wave single-axis acoustic levitation system is to determine the necessary components and parameters. This includes the type of transducers, their arrangement and frequency, and the size and shape of the levitated object.

Assembly: Once the components are determined, the system is assembled, including the transducers, power supply, and any necessary control electronics. The levitation chamber is also constructed, which is typically made of an acoustic transparent material such as glass or plastic.

Calibration: The system is calibrated to ensure that the transducers are generating a standing wave at the desired frequency and amplitude. This involves measuring the acoustic pressure distribution in the levitation chamber using a pressure sensor or microphone.

Object Levitation: The levitation process begins by placing the object in the levitation chamber and gradually increasing the acoustic pressure until the object is levitated. This may involve adjusting the transducer power or frequency, as well as the position and orientation of the object.

Control: Once the object is levitated, it can be moved along the single axis by adjusting the acoustic pressure distribution. This can be done manually or by using a feedback control system that monitors the object position and adjusts the transducer output accordingly.

Stability and Resonance: Finally, the stability of the levitated object is evaluated to ensure that it does not deviate from the desired position. Resonance frequencies are also measured to prevent the levitated object from being excited and destabilized by external vibrations or noise.

Overall, the methodology for a standing wave single-axis acoustic levitation system involves designing, assembling, calibrating, levitating, controlling, and evaluating the stability of the levitated object. This process requires careful attention to the system parameters and control strategies to ensure successful levitation and manipulation of the object along a single axis.

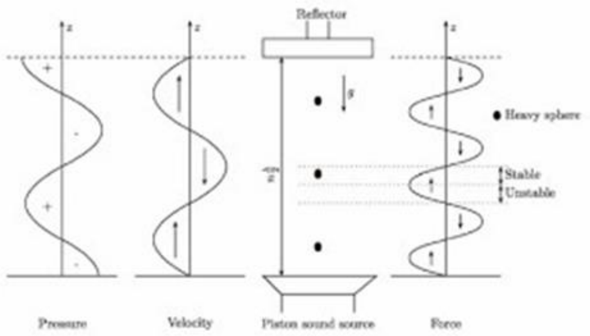

Fig -1: Formation of Nodes and Anti nodes

2.4. RESULTS AND OBSERVATION

1. The frequency of the first transducer produced is approximately 21.46KHz and the other fluctuates between the range of (19-20)KHz respectively. This is due to the fluctuations caused by the power supply voltage.
2. The approximate distance between the two transducers for them to form standing waves is found to be (1.7±0.2) centimeters. Calculation of distance between the transducer to produce standing waves:

$d = n\lambda/2$

Wavelength can be calculated from the frequency recorded, from the transducers, by the relation:

$f = cs/\lambda$

$\lambda = cs/f$

here, speed of sound in air medium is cs =343mt/s. For the arrangement made the approximate values are n = 10, hence, d = 1.5 ± 0.2.

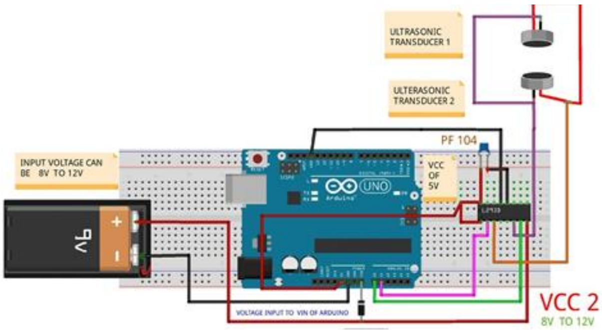

Fig -2: Circuit diagram

3. CONCLUSIONS

In conclusion, a single-axis standing wave acoustic levitation system is a remarkable technology that uses the principles of acoustic levitation to suspend small objects in mid-air. This system works by creating a standing wave between two parallel reflectors, which generates a force that can balance the weight of the object being levitated. This technology has many potential applications, including material handling, particle manipulation, and medical research. However, it also has some limitations, such as its limited ability to levitate objects larger than a few millimeters in size. Overall, the single-axis standing wave acoustic levitation system represents a promising area of research and development in the field of acoustics and engineering.

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