ISSN XXXX XXXX © 2019 IJESC

Research Article Volume 9 Issue No.3

Acoustic Levitation

Gokulraju. R[1], Kavinraj. N[2], Subramaniyan. B[3], Kulandaiyesy. P[4]
Department of Mechatronics Engineering
Akshaya College of Engineering and Technology, India

Abstract:
Acoustic Levitation is a method of suspending matter in a medium of air using Acoustic radiation pressure from intense sound wave in the medium. An acoustic levitation system is presented in this paper which can levitate planar objects much larger than the wavelength of the applied sound wave. It uses standing wave field formed by the sound radiator and the levitated planar object. An experimental setup is developed, by which a compact disc is successfully levitated at frequency of 40 kHz. The sound field is modeled according to acoustic theory. The mean excess pressure experienced by the levitated object is calculated and compared with experiment results. Nonlinear absorption coefficient is introduced into the linear model to give a more precise description of the system. The levitation force is calculated for different levitation distances and driving frequencies. The calculation results show acceptable agreement with the measurement results.

Keywords: Acoustic Levitation, Standing Wave, Large Object Levitation.

I. INTRODUCTION

Levitation is a process by which an object is suspended in a stable position against gravity, without physical contact. Levitation can be realized by various physical means, such as magnetic force, electrostatic force, aerodynamic force, acoustic radiation force and so on. An acoustic wave can exert a force on objects immersed in the wave field. These forces are normally weak, but they can become quite large when using high intensity waves due to the nonlinear characteristics. The discovery of the phenomenon of acoustic levitation goes back to 1886, when it was observed that dust particles in a Kundt's tube were concentrated at the pressure nodes of a standing wave generated in the tube. This was considered to be the effect of the non-linear acoustic radiation pressure generated by the acoustic waves the research for which was made by the paper published by King, in which he studied this nonlinear effect and derived the expression for such a standing wave field, Speculating the levitation of objects when placed at the pressure nodes of such a standing wave field-this formed the basis for the development of acoustic levitation systems. Further theoretical framework was provided from research by G'orkov and Xei and Wei, eventually leading to the development of the first acoustic levitating system by Bucks and Muller in 1933. Since then, acoustic levitation has been implemented in a number of commercial and industrial applications resulting in a number of patents regarding the same.
The system has also faced several technological leaps-in that today, not only heavy density materials like tungsten but even small animals like ladybirds and frogs can be levitated using ultrasonic levitation. The forces can even be large enough to levitate substances against gravity force. This technique is called acoustic levitation or ultrasonic levitation, when the sound waves used are in the ultrasonic frequency range (higher than 20 kHz). The researchers have been conducting studies on these phenomena to make use of sound to put to good use by creating tractor beam using sound waves. Researchers have been using many different things like superconducting magnetic fields and laser beams to levitate objects. Ultra Sound frequencies can levitate particles of a wide range of materials and sizes through air, water & biological tissues. This permits us to move cells, compounds or living things without touching them. The principle behind this technology is high frequency sound waves can produce an acoustic force on objects capable of counteracting the pull of gravity. Many ultrasound levitation devices are developed based on this principle in which the trapped particles had to be enclosed by acoustic elements. Acoustic levitation is well suited to the study of liquids including aqueous solutions, organics, soft materials, polymers, and pharmaceuticals at around room temperature. which is able to create high pitched and high intensity sound waves, generating an acoustic hologram that can lift, move, rotate and hold small objects. By controlling the output of speakers, the particles can be lifted, held stationary, moved & rotated.

II. SYSTEM DESCRIPTION

Frame
A frame is artificially build object to hold the transducers in its space, because positioning of a transducer is important for the acoustic levitation for larger objects than wave length in our methodology of work. To achieve that we design the stand in designing software that is Auto desk Fusion 360 software. And the designed product manufactured using 3D printing technology.

Figure.1.3D printed Frame

In this picture we can see that three hands are faced up and an angle of 45 degree facing up, because this angle help to always contact with the surface of the object which is larger in size. The hands have holes to place the transducers, and they have tiny hole to get the wire connection from the transducer to the driving circuit.

Ultrasonic Transducer

Piezoelectric sensors are low cost, rugged devices that are easy to drive. They are resonant devices and are available in several frequencies, depending on application. The lower frequency devices (40KHz) are low cost and can range longer distances than the higher frequency devices. The beam pattern of a transducer can be determined by the active transducer area and shape, the ultrasound wavelength, and the sound velocity of the propagation medium. The diaphragm (or membrane) principle is also used in the relatively new micro-machined ultrasonic transducers (MUTs). These devices are fabricated using silicon micro-machining technology, which is particularly useful for the fabrication of transducer arrays. The vibration of the diaphragm may be measured or induced electronically using the capacitance between the diaphragm and a closely spaced backing plate, or by adding a thin layer of piezoelectric material on diaphragm.

Figure.2.Ultrasonic Transducer

This is the exact transducer we have used in our acoustic levitation project. These transducers can give sound pressure level of 117 decibels and it consume maximum of 20 voltage. The operating temperature of -30^o to 85^{o}c. It can be used as transmitter as well as receiver.

Driving Circuit

To achieve acoustic levitation we have to switch the 20v electrical energy at 40KHz frequency.

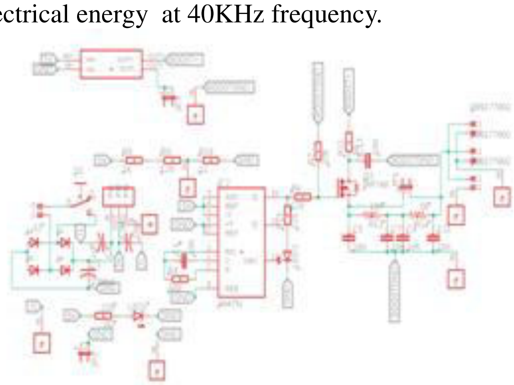

Figure.3.Circuit Diagram

This is schematic diagram of the acoustic levitation system. To design this we used Auto desk Eagle software to design the circuit and to design the Printed Circuit Board (PCB).Initially the circuit board is powered by the a transformer which can give output power of 5v, 1A at the frequency of 50Hz. Which is not sufficient to power the transducer. Then the power is converted into DC current. This dc current then boosted up using DC boost circuit. Which increase the dc current to 18 v, which is the maximum power that can consumed by the transducer. Then we have installed a ic called CD4047 multi vibrator. Which is configured to switch at the frequency of 40KHz. Then switching signal given as a gate signal to a Mosfet. This mosfet will switch the 18v dc into ac at 40KHz frequency. Then the output power is given to the piezo ultrasonic transducers. When the transducers are activated it will create a pressure in the air at a particular specified direction. It will reflected by the object which is placed in the midpoint of the system, by creating the standing wave between the object and transducers.

III. SOUND PRESSURE CALCULATION

We use the following logarithmic formula to determine the sound pressure level (SPL) in decibels.

$$\mathbf{SPL=20\log(p/p_{ref})\quad db}$$

SPL = Sound pressure level, decibels (db)

p = Sound wave pressure, Newton/meter^2 (N/m^2)

p_{ref} = Reference pressure, Newton/meter^2 (N/m^2)

The data sheet of Piezo ultrasonic transducer says the maximum pressure (p) it can create up to 117 decibels (db). And reference pressure level is considered as our human hearing capacity that is $p_0 = 2\times10^{-5}$ Pa.

Therefore,

p=117 db

convert the decibel value into pascal unit,

we know that 1pa = 94 db,

by using this key point we can convert the decibel value into pascal

therefore,

p = 117 / 94

= 1.24456 pa

p = 1.25pa

calculating sound pressure level,

SPL = 20 log (p / p_{ref})

= 20 x log (1.25 / (2×10^{-5}))

= 20 x log (62500)

= 20×4.79588

= 95.917

SPL = 95.917 pa.

From above result we can determine that One transducer can lift 0.9 gram of weight. Therefore, three transducer can lift,

lifting capacity = 3×0.9 grams

= 2.7 grams

so the lifting capacity of the our acoustic levitation system is

2.7 grams.

Through this calculation we can proof that, our design of acoustic levitation for larger objects can lift 2.7 grams of maximum of large sized objects.

IV. SYSTEM IMPLEMENTATION

In our proposed design we have implemented the acoustic levitation to levitate larger objects than the wavelength of standing wave length as per the design we have proposed. As we mentioned before the 3D printed stand was manufactured and the circuit was manufactured as PCB to make the circuit compact for the system. The system was powered using direct AC Voltage and using a transformer. Then the circuit convert the AC Voltage in to DC. Then the dc Voltage step up using boost converter. The output voltage set to 12vdc, because 12v is safest region to operate the transducers. But CD4047 cannot operate at 12v so the switching signal is given to as mosfet signal and the source pin given to 12v dc output from the boost converter. Then the out put is given to the transducer.

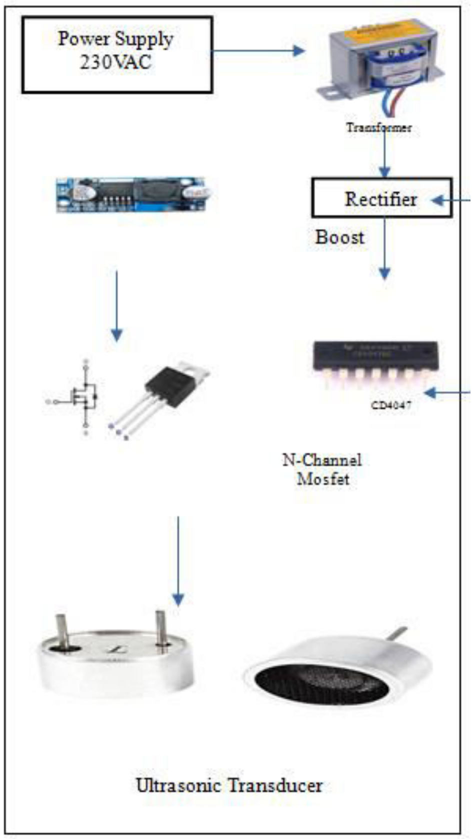

Figure.4.Block Diagram of Acoustic Levitation

This block diagram will explain the exact working of Acoustic levitation for larger objects.

Developed Hardware

After manufacturing the all components of Acoustic levitation the parts are assembled.

Figure.5.Prototype of Acoustic Levitation

The Developed hardware is shown in Fig5. From the figure we can see that the transducers are placed in the hand holes and the PCB was placed in the leg bed. The power supply was given by the transformer and the sound pressure was created between the transducers.

V. RESULT

The Acoustic levitation using in this design was successfully assembled and the circuit was successfully operated. The calculated sound pressure level is successfully generated by the ultrasonic transducers. And the Standing wave of three transducers are successfully generated. The large object then the size of standing wave length is levitated successfully.

VI. CONCLUSION

In this paper the acoustic levitation of larger objects than the standing wave length is discussed. Basic principle behind the acoustic levitation of larger objects is creating a standing wave between the transducer and the surface of the object, this will create an acoustic pressure between the object and transducer. This pressure will hold the object of larger than wavelength of standing wave and the weight of 2.7 grams in the middle of air.

VII. FUTURE WORK

The ongoing and future work is to increase the load carrying capacity to use the acoustic levitation in industries to transfer most delicate materials and to make a medical device to help doctors to implement medicine by using the technique called non-invasive operation and to handle the micro and macro surgical instruments.

VIII. REFERENCES

[1]. A standing wave acoustic levitation system for large planar objects, 2015. by Zhao · Jorg Wallaschek, Institute for Dynamics and Vibration Research, Appelstr. 11, 30167 Hannover, Germany.

[2]. Acoustic levitation made simple, 5-jan-2015. by physics.org,

[3].The Development of an Acoustic Levitation Test by Victor D. Lupi, 1998. Massachusetts Institute of Technology,.

[4]. A study on Acoustic Tractor Beam Technology, 2016. by Ms.Sudha T, Asst.Prof. Ms.Rini M K, Asst.Prof.Ms.Vincy Devi V.K.

[5]. Acoustic levitation, 2015. bySaša Hrka doc. Dr. Daniel Svenšek Ljubljana.

[6]. Acoustic Levitation: Theoretical Exploration 22July2016. By Sarah Fontana, Devin Moeller, Kimberly Robins, Irina Liu, New Jersey Governor’s School of Engineering and Technology.