Acoustic Radiation Force in Mid-air Ultrasound

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Abstract

Acoustic Radiation Force is the force produced by sound wave. When there is the superposition of sound wave, it would appear the place of maximum of force called “focal point”. The property of focal point would change according the degree of sound transmitter and it proportional to the inverse of the distance.

Introduction

Superposition of ultrasound can make a touchable space[1]. Thus, we know that sound wave can produce “force”. The place where superposition of sound wave called” focal point”. In this study, we would use different size paper to research the value of acoustic radiation force work on different shape of object at different height and the find out the distribution of acoustic radiation force in a space.

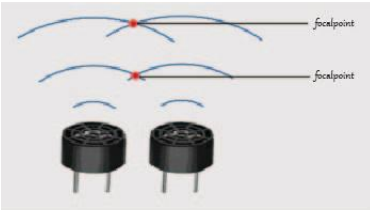

***Figure 1**, illustration of focal point.*

Experimental setup

We set up a platform which can adjust height with stepping motor and put ultrasound device under it. Besides, we installed a red screw in platform and used tracker to track height.

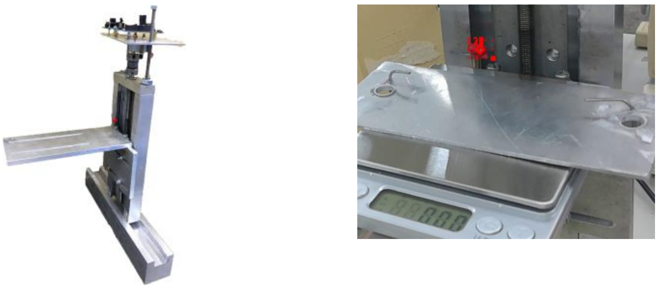

***Figure 2,** the device to control platform at different height.*

We chose MA40S4S to be out ultrasound transmitter. It has best efficacy at 40kHz and 16Vp.p. For driving ten MA40S4S, we used power amplifier to amplify the signal which produced by function generator. On the other hand, we want to make ultrasound more concentrated, so we design arc-shaped support to place ultrasound.

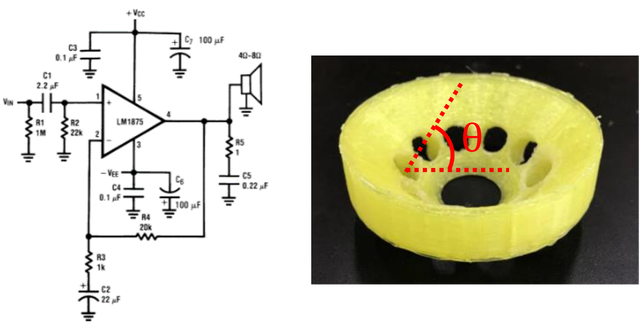

***Figure 3,** the typical application of LM1875 and the arc-shaped support of ultrasound*

Results and Discussion

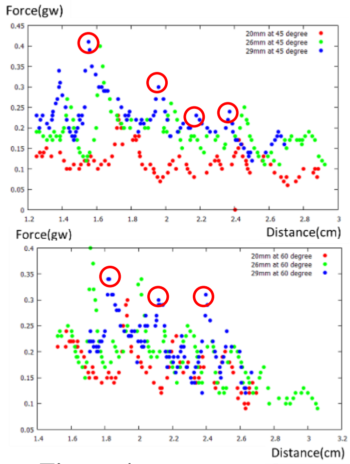

***Figure 4**, acoustic radiation force of 45⁰ and 60⁰.*

From **Figure 4**, we can observe the place of red circle where acoustic radiation force is bigger that value nearby is focal point. When contact area increase, the acoustic radiation force would increase. To acoustic radiation force, the influences of degree seems not obvious. But big degree would make focal point higher.

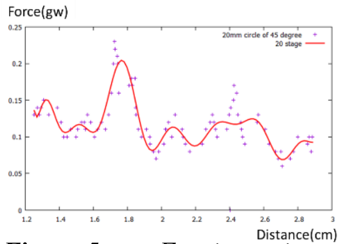

***Figure 5**, use Fourier series to fit force.*

We assume that the force might be made up of many different waves. Therefore, we used Fourier series to fit it. By using twenty wave numbers, we find that the first one is approximately 0.9. The value we assumed is 7.3, which is the eighth wave number in the series. Which also implies us that the result wave is consist of wave that have higher or lower frequency.

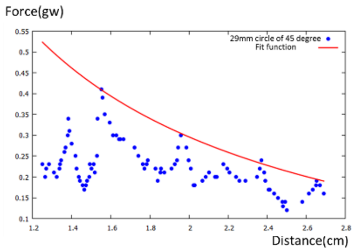

***Figure 6**, trend line of 29mm circle 45⁰.*

The decrease of the force may cause by the energy lose. While the energy of the ultrasound loses with the square of the distance, the amplitude of the sound wave will be proportional to the inverse of the distance, and so does the force.

Conclusion

1. The acoustic force comes from the array is the superposition of many different waves, including those frequencies higher or lower than the original one. They appear differently under different angles.
2. When the distance gets larger the wave become intensive, because of the angle between the vertical line and the direction of wave propagation.
3. The decrease of the energy cause the amplitude of the wave reduce, which makes the force be proportional to the inverse of the distance. The bigger area can receive more force at the same height of the transducers.

Reference

1. "Rendering Volumetric Haptic Shapes in Mid-air Using Ultrasound" by Benjamin Long et al.2014
2. "Noncontact Tactile Display Based on Radiation Pressure of Airborne Ultrasound" by Takayuki Hoshi et al.2010.