TELKOMNIKA, Vol. 11, No. 2, February 2013, pp. 689~693
ISSN: 2302-4046

Distance Characteristics of Sound Wave Attenuation in ER Fluids

Nanhui Yu[1], Jijun Fan[2]
[1]School of Mechanical Engineering, Wuhan Polytechnic University, Wuhan, China
[2]School of Electric and Electronic Engineering, Wuhan Polytechnic University, Wuhan, China
e-mail: nanhui_yu@hotmail.com[1], jijun_fan@hotmail.com[2]

Abstract

Electrorheological fluids (ER fluid) as an electrically controllable acoustic medium has been proved by experimental studies. In this paper, the sound attenuation in ER fluid at different propagation distances was experimentally studied. The results show that sound attenuation of ER fluid could be adjusted by the particle concentration of ER fluid and the intensity of electric field. Amplitude of sound wave in ER fluid increases with the increasing of particle concentration and field intensity; on the other hand, the attenuation of sound wave decreases with the increasing of propagation distance, as well as the particle concentration and field intensity. The experimental results indicate that the solidification effect of ER fluid is beneficial to the propagation of sound wave.

Keywords: *sound wave, propagation distance, attenuation, ER fluid*

1. Introduction

ER fluid is a kind of suspension liquid with special response to extra electric field [1]. As a smart material, when there is no extra electric field, it behaves as Newtonian fluid; however, when extra electric field is applied, the solid particles in ER fluid are polarized and interact with each other, then a chain-like or column-like structure parallel to the field is formed, thus resulting in a significant increase in its apparent viscosity, then the ER fluid exhibits characteristics of non-Newtonian fluid [2]. This sort of structural transformation is rapid and reversible, thus giving rise to a wide research interest. Lots of research indicates that ER fluid can be regulated and controlled on its mechanical properties by extra electric field, so it has a wide application prospect. At the same time, much research also have been done on the regulation and controllability of its optical behavior in recent years, for example, Jijun Fan et al. have studied the laws of transmission, reflection, attenuation and so on when microwave passes through ER fluid [3-5].

When ER fluid is acted on by extra electric field, distinctive changes may happen on its internal structure, not only its mechanical and optical properties can be regulated and controlled with the changing of extra electric field, but also it have great influence on the propagation behavior on the sound wave. Guicking et al. have measured velocity and attenuation in ER fluid [6]. Duan et al. have studied the changes of sound impedance in ER fluid [7, 8]. Hong Tang et al. have done some research on the frequency spectrum and phase change of sound wave passing through ER fluid [9]. In this paper, some experimental studies have been done on the attenuation behavior of sound wave in ER fluid, and the controllability of sound wave going through ER fluid is discussed.

2. Research Method

2.1. Experiment materials and instruments

Taking silicon dioxide and dimethyl silicone oil to make ER fluid, three samples were prepared, mass concentration percentage of which were 10%, 20% and 30% respectively. As shown in Figure 1, a container using for placing ER fluid was designed out with its size of 60×55×5mm (height×width×thickness), made up of organic sheet; the electrodes were made by copper sheet, which were placed on the two side faces of container.

Received August 30, 2012; Revised December 23, 2012; Accepted January 12, 2013

The instruments needed in this experiment included: velocimeter, oscilloscope, LF signal generator, high voltage DC power supply, piezoceramic plane loudspeaker et al.

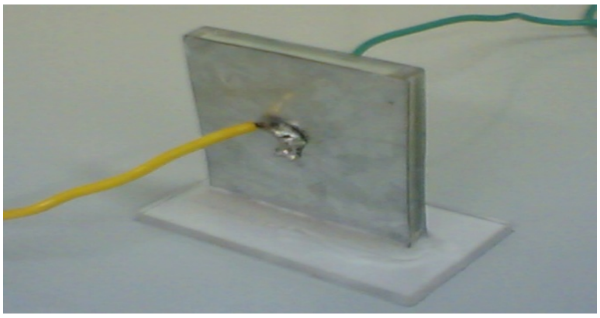

Figure 1. ER fluid sample container

2.2. Experimental procedure and principle

Experimental set-up is illustrated in Figure 2. The velocimeter was equipped with two piezoceramic plane loudspeakers S1 and S2, S1 was connected to the LF signal generator, served as ultrasonic sorce; S2 was connected to the oscilloscope, served as receiver. Meanwhile, the oscilloscope was also connected to the generator. The ER fluid sample was put into container, and placed between S1 and S2, the positive and negative electrodes of high voltage DC power supply were connected with those two electrodes on two size faces of container respectively.

Standing-wave resonance method was adopted in this experiment. Using LF signal generator to output the natural frequency of standing-wave system, asjusting the distance between S1 and S2, then give the wave form on the oscilloscope. The ER fluid sample was placed between S1 and S2, its state could be changed by adjusting voltage of DC power supply. Measuring the maximum amplitude of every wave form occuring during this distance and record the value of this distance.

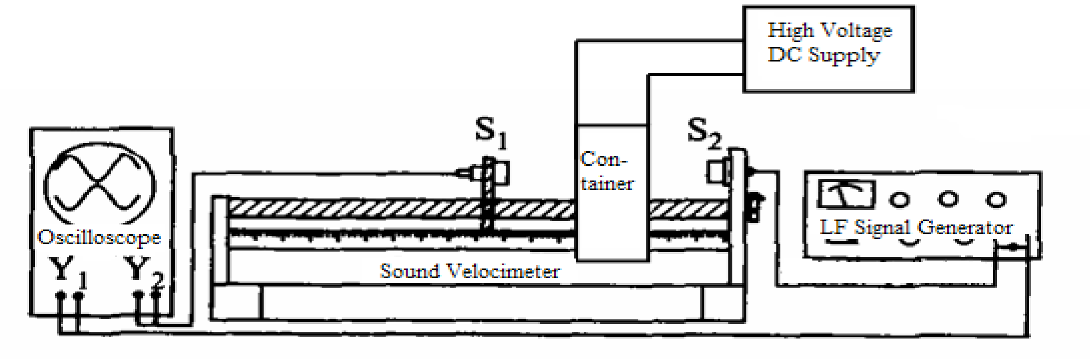

Figure 2. Experimental set-up diagram

3. Results and Analysis

Figure 3 gives three attenuation curves of sound wave varying with distance when it passes through air, empty container and container with silicon oil respectively. It illustrates that when the distance is fixed, the maximum amplitude of sound wave occurs when it goes through container with oil, next is empty container, the minimum is air; moreover, the sound wave all presents monotonic decreasing trend with the increasing of distance when it goes through the above three different mediums.

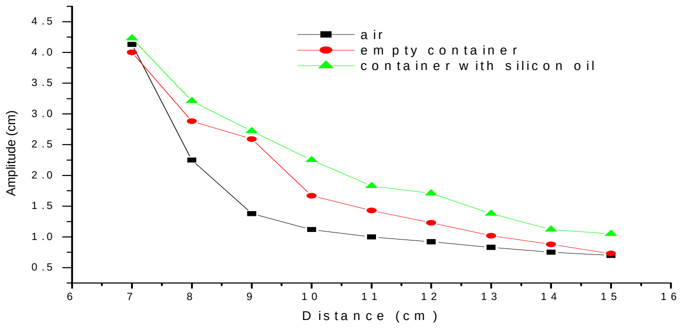

Figure 3. Sound amplitude varies with distance in different mediums

Figure 4 shows three attenuation curves of sound wave varying with distance when sample concentration of ER fluid are 10%, 20% and 30% respectively and no electric field is applied. It indicates that when the distance is fixed, the maximum amplitude of sound wave passing through ER fluid occurs when the concentration of fulid is 30%, next is 20%, the minimum is 10%, that is to say, the amplitude is increasing with the increase of concentration; moreover, the sound wave all has decreasing state with the increasing of distance when it goes through the above fluids with three different concentration, however, the attenuation trend slows down with the increasing of concentration.

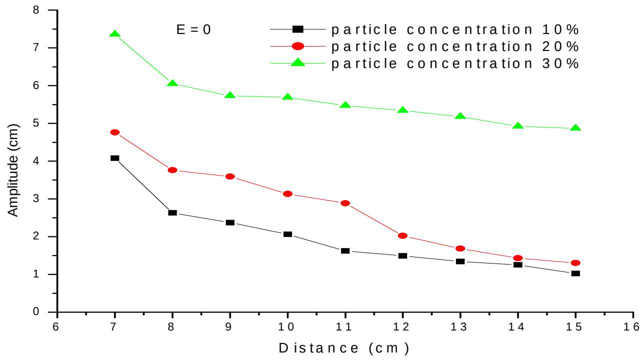

Figure 4. Sound amplitude varies with propagation distance and particle Concentration without electric field

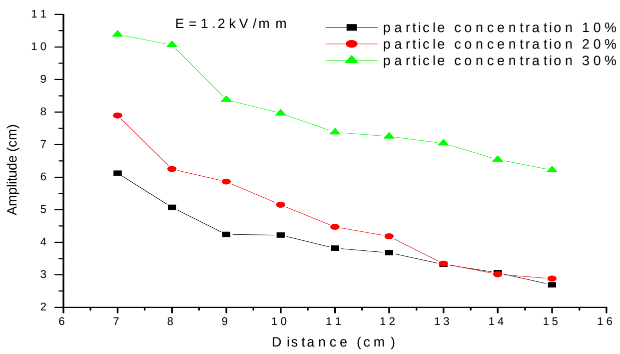

Figure 5. Sound amplitude varies with propagation distance and particle Concentration under the same electric field

Figure 5 exhibits three attenuation curves of sound wave varying with distance when sample concentration of ER fluid are 10%, 20% and 30% respectively and an electric field of 1.2kV/mm is applied. Comparing with Figure 4, it is obvious that they have similar changing rules, that is, the amplitude of sound wave passing through ER fluid is increasing with the increase of concentration; meanwhile, it presents attenuation when the distance increases, its trend slows down with the increasing of concentration. However, the difference between them can also be found, when the concentration is fixed, the sound wave passing through ER fluid with electric field is larger than without it.

Figure 6 shows three attenuation curves of sound wave varying with distance when the intensity of applied electric field are 0.5kV/mm, 0.75kV/mm and 1.0kV/mm respectively and the sample concentration of ER fluid is 20%. It illustrates that when the distance is fixed, the maximum amplitude of sound wave passing through ER fluid occurs when the intensity of electric field is 1.0kV/mm, next is 0.75kV/mm, the minimum is 0.5kV/mm, that is to say, the amplitude is increasing with the increase of electric field; moreover, the amplitude of sound wave passing through ER fluid all presents decreasing state with the increasing of distance under three different electric field, however, the attenuation trend slows down with the increasing of intensity of electric field.

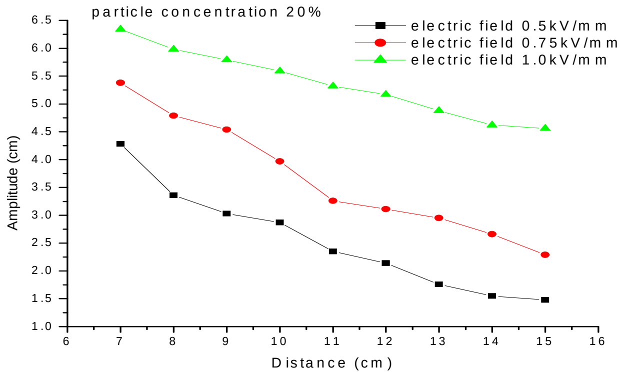

Figure 6. Sound amplitude varies with propagation distance and electric field at the same particle concentration

Figure 7 gives three curves of sound wave varying with electric field when sample concentration of ER fluid are 10%, 20% and 30% respectively. It illustrates that when the distance is fixed, the attenuation amplitude of sound wave passing through ER fluid is increasing with the increase of concentration, as well as electric field intensity.

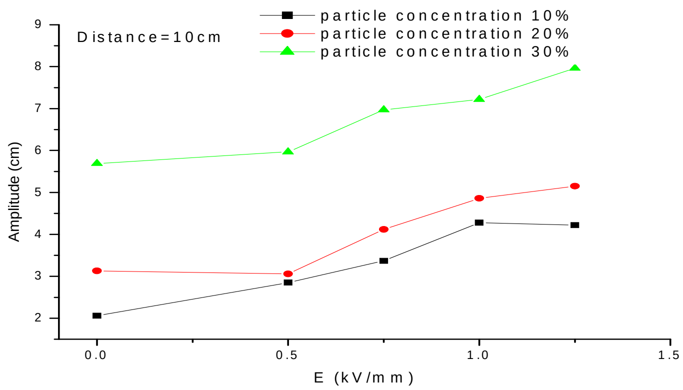

Figure 7. Sound amplitude varies with electric field and particle concentration at fixed distance

Figure 8 exhibits three curves of sound wave varying with particle concentration when the intensity of applied electric field are 0 kV/mm, 0.5kV/mm, 0.75 kV/mm, 1.0 kV/mm and 1.2 kV/mm respectively. It also indicates that when the distance is fixed, the attenuation amplitude of sound wave passing through ER fluid is increasing with the increase of electric field intensity as well as particle concentration.

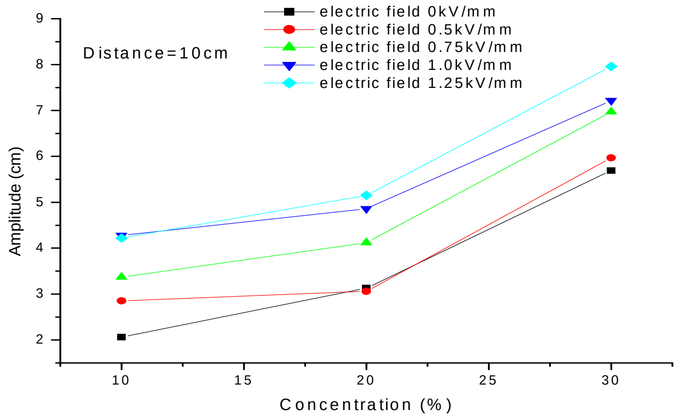

Figure 8. Sound amplitude varies with particle concentration and electric field at fixed distance

4. Conclusion

The attenuation of sound wave in ER fluid at different propagation distances was studied experimentally. The experimental results showed that the amplitude of sound wave in ER fluid increases with the increasing of particle concentration and electric field; meanwhile, sound attenuation decreases with the increasing of propagation distance, and increases with the increasing of particle concentration and electric field.

It is regarded as that the solidification effect of ER fluid under electric field may be conductive to the sound propagation in ER fluids.

References

[1] Whittle M, Bullough WA. The Structure of Smart Fluids. *Nature*.1992; 358: 373.
[2] Halsey T. Electrorheological Fluids. *Science*. 1992; 258(5083): 761-766.
[3] Fan JJ, Zhao XP, Huang M, Guan LT, Wen LS. Adjustable Character of Microwave Attenuation in Batio3 Electrorheological Fluids. *Progress in Natural Science*. 2002; 12(10): 1070-1074.
[4] Fan JJ, Zhao XP, Gao XM, Cao CN. Electric Field Regulating Behaviour of Microwave Propagation in ER Fluids. *J Phys D: Appl Phys*. 2002; 35(1): 88-94.
[5] Huang M, Zhao XP, Wang BX, Yin JB, Cao CN. Modulatory Character of Microwave Reflection Behavior in Electrorheological Fluids. *Acta Physica Sinica*. 2004; 53(6): 1895-1899.
[6] Guicking D, Wicker K, Eberius C. Electrorheological Fluids as an Electrically Controllable Acoustic Medium: I. Experimental Arrangement and Application to an Absorber of Underwater Sound. *Acta Acustica United with Acustica*. 2002; 88(6): 886-895.
[7] Duan XD, Wu W, Zhou TY, Luo WL. Evidence of Nematic Phases in Electrorheological Fluid by Acoustic Impedance Measurement. *J Phys D: Appl Phys*. 2000; 33(7): 57.
[8] Ding LH, Huang QB, Wang JL, Zhang Q. Research of Acoustic Wave Propagation Characteristics in Electrorheological Fluids by Transmission Matrix Method. *Journal of Huazhong University of Science and Technology(Natural Science Edition)*. 2010; 38 (7): 5-7.
[9] Tang H, Luo CR, Zhao XP. Sound transmission behavior through a sandwiched electrorheological layer. *Acta Materiae Compositae Sinica*. 2006; 23(2): 128-132.