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Anomalous and Instable Ultrasonic Evidence for a Structural Phase Transition at the Critical Value V_c in Electrorheological Suspensions

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Abstract: Using the sample cell designed by ourselves and the electrorheological (ER) samples, one of them is imported from USA (sample 1), the other one is made from tsinghua university (sample2), we perform a series experiments with these two ER samples, and observe some curious phenomena; such as the ultrasonic study on the longitudinal sound velocity in electrorheological (ER) suspensions reveals the existence of a serious shear instability at the critical value of applied voltages, the evidence retains the time of about a few milliseconds; moreover, the experiments on ER samples demonstrate that there is a saturation value for the ultrasonic attenuation when the applied voltages arrive a critical value V_c, which resemble to the cases of a lot of superconductors at the critical value of temperature T_c; In the experiments on the I-V characteristic of the two ER samples, we observe that an abrupt change in the I-V characteristics occurs at the critical value V_c of the applied voltages, furthermore, the I-V characteristic of either of the two ER samples is linear after the applied voltages overpass the critical value V_c, just as same as the I-V characteristic of metal conductors. Therefore, it is reasonable to suggest that this anomalous ultrasonic evidence we observed in the experiments corresponds to a structural phase transition from liquidlike phase to metal-solidlike phase in the electrorheological suspensions.

Keywords: Electrorheological Suspension, Anomalous Ultrasonic Evidence, Attenuation, I-V Characteristics, Phase Transition

1. Introduction

It has long been known the fact which as the external voltage of applying to an electrorheologcal (ER) suspension is increased up to a critical value V_c, the ER suspension suddenly manifests a series of curious properties in viscosity, electricity, and others [1-9]. Up till the recent years, researchers still published a lot of studies on the topics related to ER suspensions [10-13]. However, we have not yet clearly known what is the mechanism of the so-called ER effects, therefore, it is important to seek out the particular features which are common to all of the ER suspensions, in this regard, it is significant to investigate the nature of the particle–particle interactions, and how these interactions are related to the properties of ER materials. Moreover, in a lot of experiments we discovered that there is another such prominent feature, the existence of structural instabilities.

With respect to the experiments of studying the properties of ER suspensions, some of the early measurements have shown how the ultrasonic attenuation in ER suspensions depends on the applied electric fields [5, 14]. In 1994, we designed an experiment for a few ER samples to undertake a series of preliminary measurements on the sound velocity, the ultrasonic attenuations, the I–V characteristics, and so on, we surprisingly observed a few strange phenomena common to all the ER suspensions, which merits our interest and further study.

2. Experimental Set

In our experiments, the ultrasonic system consists of a 0.8 MHzP wave transducer and a SAMPOSS202020MHz Dual

Trace Oscilloscope, the sample cell is made from the copper material, which strongly resemble to that of W. M. Winslow used in his experiments [1]. Moreover, in measurements, we set the pulse frequencies ranged from 30 to 100KHz, pulse widths ranged from 100ns to 300ns, and at a set delay (time/div) of 1 μs /div.

3. Experimental Results

3.1. Anomalous Evidence

Measuring the longitudinal sound velocity of passing through an ER suspension (sample 1) was carefully controlled at the room temperature, with increasing of the applied voltage up to the critical value V_c, we observed on the oscilloscope that, probably with in the time of milliseconds, sample 1 suddenly manifested a serious instability, instantaneously accompanied an extremely high wave peak. Due to some technical reasons, it was incapable of taking a photo for the anomalous evidence in so short time's interval. It may be of significance that such an anomalous and instable ultrasonic evidence usually occurs in a lot of superconductors at a critical value of the temperature T_c. [15].

3.2. Attenuation

Meanwhile, we precisely measured the ultrasonic attenuation in sample 1 under the applied voltages ranged from 10kV to 14kV, but no any change in the ultrasonic attenuation could be observed as we gradually increased the applied voltage, the experimental results are tabulated at below:

Table 1. *The ultrasonic attenuation in sample 1.*

Sample	Applied voltage (kV)	Retaining time (minute)	Ultrasonic attenuation (μS)
1	10	30	no
	11	8	no
	12	16	no
	13	7	no
	14	11	no

Table 1 demonstrates that there must be a saturation value for the ultrasonic attenuation.

3.3. I–V Characteristic

In order to find some common features related to the I-V characteristics from various ER suspensions, we comparatively performed a series of measurements respectively on two ER suspensions (samples 1 and 2), which are different from each other in manufacture, and some of the experimental data are plotted in figure 1, in this figure, it shows the principal difference between these two samples in quality.

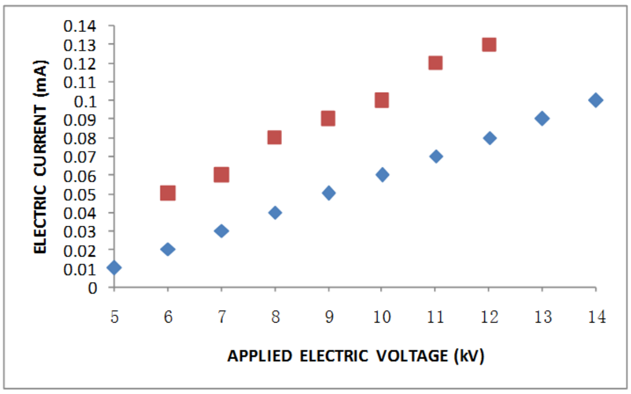

Figure 1. *The I-V characteristics of samples 1 and 2. In the diagram, the blue points represent the experimental data of sample 1, and the red points represent the experimental data of sample 2.*

In the experiments for sample 1, we observed that after the applied voltages exceeding the critical value, the variation of the wave peak of electric current becomes very steady, Figure 1 merely exhibits a part of the experimental data, therefore, even if we successively increase the applied voltage more higher, the electric current will rigorously retain a linear dependence on the applied voltage.

Similarly, from Figure 1 it can be found that all of the experimental data for sample 2 can also nearly superpose with a straight line. Nevertheless, once the applied voltage exceeds 13kV, we observed the phenomenon of break down, the values of electric currents slowly increasing away from the straight line.

Dealing with the mathematics, if no the phenomenon of break down occurs in higher applied voltage, from the experimental data shown in figure 1, the I-V characteristics of samples1 and 2, as well as other ER suspensions can be always summarized by the equation:

$$I=\kappa V+C, \qquad (1)$$

Where κ is a coefficient, C is a constant, either of their values depends on the ER suspension we employ, for example, if the unit of V is volt and of I is ampere, for sample 1, $\kappa=10^{-8}$, $C=-4\times10^{-5}$; but for sample 2, $\kappa\cong1.333\times10^{-8}$, $C=-3\times10^{-5}$.

Summarily, no matter what an ER suspension consists of, after the applied voltage exceeds a critical value V_c, eq. (1) can satisfactorily summarize its I-V characteristic.

4. Discussion and Conclusion

In experiments of measuring the longitudinal sound velocity of passing through sample 1, when the applied voltage is increased up to the critical value V_c, we surprisingly observed, may be in a few milliseconds, the occurrence of an anomalous and instable ultrasonic evidence.

Moreover, our experiments have proven that there must be a saturation point for the ultrasonic attenuation in ER suspensions, this is compatible with a number of superconductor materials when the temperature overpasses a critical value T_c [15]. Although T_c and V_c are different in the conception, the both commonly result in sudden change in the I-V characteristic. On the other hand, with respect to any ER suspension, after the applied voltage exceeding the critical value V_c, the I–V characteristic strongly resemble to that of metal conductors, but not that of all of the solids, such as semiconductors and insulators, in fact, eq. (1) is consistent with the I–V relation for metal conductors $I = \frac{V}{R}$, nevertheless, the I-V characteristic of semiconductors is a curve, not a straight line. However, an ER suspension can not be applied as a metal conductor, because the resistance of the metallike ER suspension is much stronger than that of metal conductors; for example, for sample 1, in eq. (1), $\kappa = 10^{-8}$, the electric current passing through the ER suspension would be very slim. In consideration of these experimental results, it is reasonable to suggest that the anomalous and instable ultrasonic evidence we discovered in the experiments arises from a structural phase transition, from the liquidlike phase to the metal-solidlike phase of an ER suspension.

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