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On the Ultrasonic Velocity in Suspension

By

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The ultrasonic velocity in suspension and the temperature dependence of the velocity were measured for the various specimens. In this paper, the experimental result is alone described.

§ 1. Introduction.

The informations of the velocity of ultrasonic waves in suspension have been given by HERTZFELD[1], SWELL[2], RANDALL[3] and URICK[4]. RANDALL determined the ultrasonic velocity in suspension by the method of acoustic interferometer. But the agreement between RANDALL's experimental result and HERTZFELD's theoretical one is unsatisfactory. Indeed, the propagation of ultrasonic waves in suspension may be complex character. According to HERTZFELD's theory, the variation of the ultrasonic velocity in suspension originates from the scattering of the ultrasonic waves by the suspending particles. When the primary wave falls on a small particle, the particle emits a scattered wave. In suspension, there will appear phase difference between the primary wave and the resultant wave composed of the primary wave and the scattered waves which are emitted from all suspending particles. This will account to the same thing as if the primary wave has a different velocity of propagation in suspension. Since the phase difference between the primary wave and the above described resultant wave may vary with the relative motion of the particles with respect to the suspending liquid, the viscosity is considered to be an important factor which causes the variation of ultrasonic velocity.

However, in the suspensions, the colloidal particles are usually surrounded by an ionic atmosphere. Then in the ultrasonic field, the ionic atmosphere may have an effect upon the motion of the

charged colloidal particles. Therefore the ionic atmosphere may also take some role which contributes to the variation of ultrasonic velocity in the suspension. No matter whether the dispersed particles may be surrounded by the ionic atmosphere or not, the relative motion of the particles with respect to the suspending liquid may show a complicated variation according to the change of the frequency of the sound waves.

In this paper, the velocity of ultrasonic waves and the variation of the velocity as regard to temperature change of the specimen were measured over the wide range of frequency.

§ 2. Experimental Method.

For the generation of the ultrasonic waves, X–cut quartz plates of various thickness were used. The electrical circuit was HARTLY type.

For the higher frequency of the ultrasonic waves than 1000 KC, the velocity of ultrasonic waves was measured by making use of the diffraction of light in the ultrasonic field. The optical system is shown in Fig. 1.

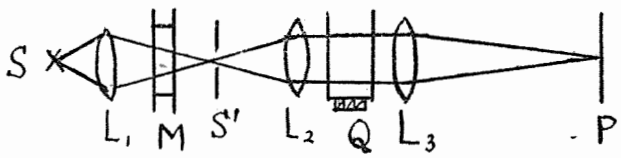

Fig. 1. Schematic diagram of the optical system.
S: Hg-lamp, Q: Quartz plate,
P: Photographic plate, L_1, L_2, L_3,: Lens,
S′ Slit, M: Monochromator.

For the frequency of the waves lower than 1000 KC, the lens L_3 is removed and the wave length of the waves in the specimen is directly measured by projecting the parallel ray into the ultrasonic field.

The specimens used in this experiment are the following:

1) the suspension of very fine powder ($\sim 10^{-4}$ cm) of quartz in water, methyl-alcohol, NaCl–solution and KOH solution,

2) the suspension of lycopodium in water,
3) the solution of gelatin and the colloidal solution of gum arabic.
In this experiment, these specimens were not out-gased.

To prevent the specimen from the disturbance caused by the temperature change by ultrasonics, it is preferable to use the waves of weak intensity, so far as the measurement is possible.

§ 3. Experimental Result.

When the suspensions of fine powder of quartz in water and in methyl-alcohol are used, the ratio of the sound velocity in suspension (V) to the velocity in the suspending liquid (V_0) varies with frequency (f) of the sound waves as shown in Fig. 2.

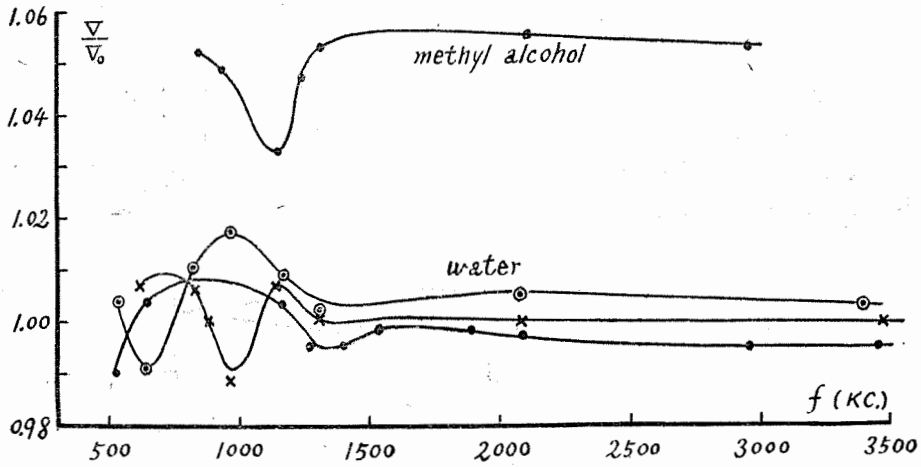

Fig. 2. V/V_0 as a function of frequency of the sound waves.

The range of the frequency at which the dispersion appears is the lower, with increasing the degree of the concentration of the particles in suspension. For the suspending liquids of two kinds (i.e. water, methyl-alcohol), the character of curve is similar but the ratio V/V_0 is far larger in methyl-alcohol than the one in water. The ultrasonic velocity in the suspension increases with the temperature of the specimen and the ratio of the amount of the increment of velocity to temperature rise ($\Delta V/\Delta\theta$) is a function of temper-

ature of the specimen and the frequency of the sound.

The observed ($\Delta V/\Delta\theta$) is shown in Fig. 3 as a function of temperature of the specimen.

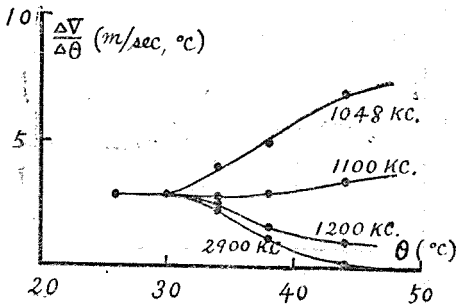

Fig. 3. $\Delta V/\Delta\theta$ as a function of temperature of specimen.

When water is used as the suspending liquid, in lower range of temperature than 30°C, $\Delta V/\Delta\theta$ is independent of temperature of the specimen and the frequency of the sound. The increment of $\Delta V/\Delta\theta$ by the existence of the suspending particles is about 0.4 m/sec, °C, since $\Delta V/\Delta\theta$ of pure water is 2.5 m/sec, °C. On the other hand, in a certain temperature range higher than 30 °C, $\Delta V/\Delta\theta$ becomes to depend upon temperature of the specimen and the frequency of the sound. As shown in Fig. 3, the variations of $\Delta V/\Delta\theta$ with regard to temperature are positive for comparatively low frequency of the sound, while for higher frequency they are negative. When the strong electolytic solution (NaCl or KOH) is used as the suspending liquid, at the frequency 1100 KC, temperature dependency ($\Delta V/\Delta\theta$) of the specimen in the region of higher temperature than 20°C is far larger than that of the case of water, while at high frequency 2900 KC, even if the strong electrolytic solution is used as suspending liquid, $\Delta V/\Delta\theta$ tends to zero at a certain temperature. (Fig. 4)

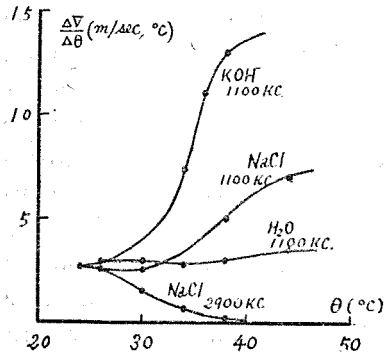

Fig. 4.

The experimental results with respect to the suspension of lycopodium in water, colloidal solution of gum arabic and gelatin solution are shown in Fig. 5. In fact, the experimental result points out the existence of the dispersion of the ultrasonic velocity in the suspension. But, unfortunately, our result contains two uncertainties, quantitatively: First uncertainty is due to the fact that in our experiment the intensity of the waves was not measured. There

may exist some deviation of intensity among the waves of various frequency. The second one is the influence of cavitation on the supersonic velocity; it is supposed that the possibility of occurrence of the cavitation may increase by the existence of the suspended particles. Especially in the methyl-alcohol it is expected that the cavitation acts to induce a depolymerisation which causes the velocity variation in the specimen. An origin of the large value of V/V_0 in the case of the suspension in methyl alcohol may be attributed to the depolymerisation by the cavitation.

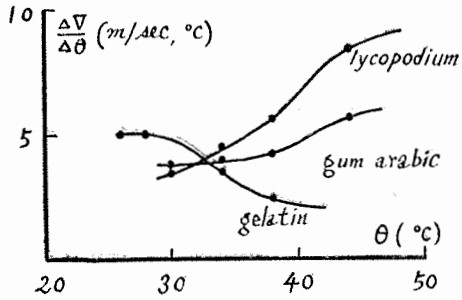

Fig. 5.

§ 4. Conclusion.

As described in §1 it may be reasonable to consider that the important factors, which contribute to the variation of the sound velocity in the suspension, are the viscosity and the existance of ionic atmosphere. The affection of viscosity upon the ultrasonic velocity in the suspension may decrease with increasing temperature of the specimen. Besides, according to the result of our investigation on the behavior of ionic atmosphere in the ultrasonic field, the influence of ionic atmosphere on the ultrasonic velocity is expected to increase with the temperature of the specimen. Our experimental result may be explained from such point of view. In this first report the experimental data is alone described.

References.

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