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Measurements of ultrasound attenuation in suspended sediment

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1. Introduction

Sound attenuation in suspended sediment can be considered as a sum of attenuations in clear water and sediment. The sediment attenuation is again considered as a sum of viscous and scattering absorptions, which are strongly affected by distribution of sediment particle size [1]. Generally, sediment attenuation models to predict sound attenuation in suspension use a mean particle size as an input parameter. However, because the suspended sediments in the ocean consist of various sized particles, it sometimes causes an error between the measured attenuation value and model prediction. In this paper, the attenuation measurements using ultrasound wave were made for several types of particle-size distribution and their concentration changes. The results are compared to the model predictions.

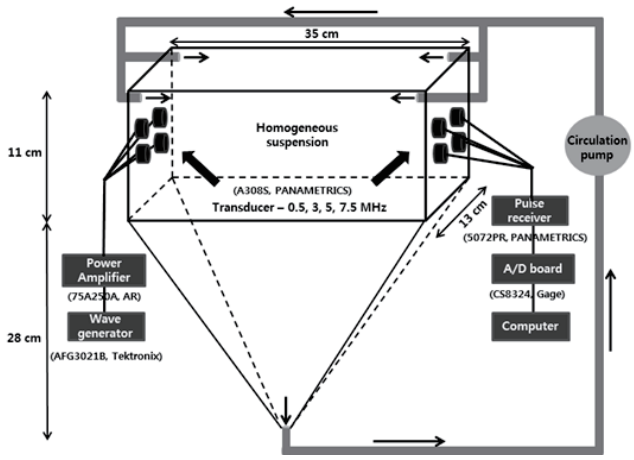

Fig. 1 Experimental geometry for sediment attenuation measurements in laboratory.

2. Laboratory Measurements

Ultrasound attenuation measurements were made for 3-types of artificially induced suspended sediment samples; kaolinite, pink-kaolinite, and their mixture. A total of eight ultrasound transducers were used, and each two transducers were aligned face-to-face in a PVC water tank, each comprising a transmitter and receiver pair [**Fig. 1**]. A circulation pump was used to keep the suspended fluid homogeneous. The water temperature was measured continuously using a digital thermometer installed in the water tank. Concentrations of suspension were in a range from 0 to 10 g/l. Continuous waves (CW) with center frequencies of 0.5, 3, 5 and 7.5 MHz were transmitted with a pulse length of 0.5 μs from the transducers. **Fig. 2** shows particle-size distribution (in ϕ scale) of each sample. Mean particle size ($x_{\emptyset}$) for each distribution was estimated using the logarithmic method of moments defined by [2]

$$x_{\emptyset} = \frac{\sum p_{\emptyset} m_{\emptyset}}{100}, \quad (1)$$

where, $p_{\emptyset}$ is a percentage of each ϕ size and $m_{\emptyset}$ is the mid-point value in the interval for each ϕ bin. The values of mean particle size for the samples of kaolinite, pink-kaolinite, and the mixture were estimated to be 32.5, 46.3 and 38.8 μm, respectively, which were used as input parameters in the attenuation model.

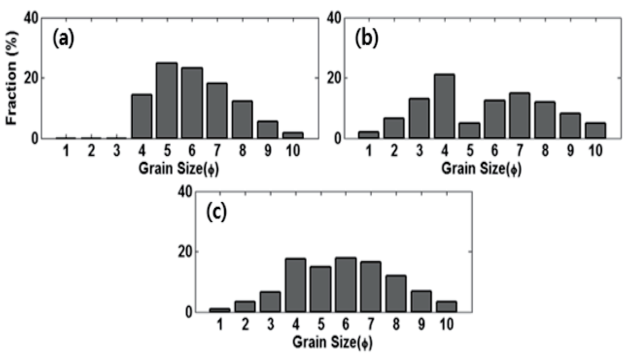

Fig. 2 Particle size distribution of (a) kaolinite, (b) pink-kaolinite and (c) mixed sediment.

3. Results

Fig. 3 shows the estimated attenuation coefficients in the suspended sediments as a

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function of concentration and their comparisons to model predictions obtained using the sediment attenuation model. First, model prediction was made using a mean particle size estimated using Eq. (1), and the model outputs are shown by solid lines in Fig. 3. For the frequencies of 0.5, 3, and 5 MHz, the measurements reasonably agree with the model predictions for every case except at pink-kaolinite for 5 MHz. However, there is no agreement between the model predictions and the measurements for the 7.5 MHz. This disagreement may happen because the mid-point value in the interval for each bin does not represent the dominant particle size within each bin.

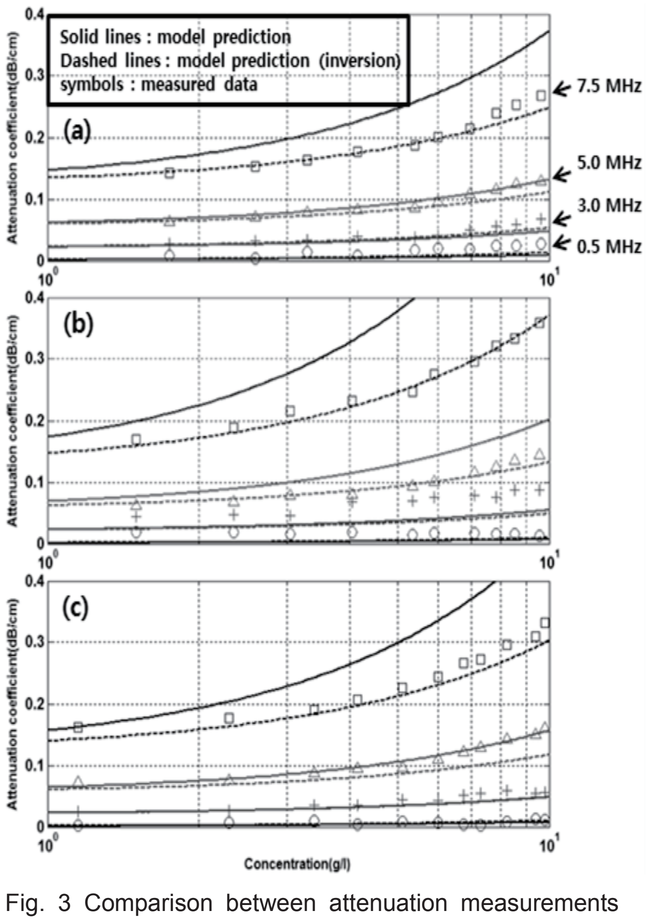

Fig. 3 Comparison between attenuation measurements and model predictions using mean particle size as a model input for (a) kaolinite sample, (b) pink-kaolinite sample, (c) mixed sample.

To find the dominant particle size for each bin, an inversion processing was conducted using genetic algorithm (GA) [3], and the inversion results were used as m_{ϕ} in Eq. (1). The best values of mean particle size estimated by the inversion processing for the samples of kaolinite, pink-kaolinite, and their mixture were estimated to be 21.8, 32.2, and 27.6 μm, respectively. The model predictions were then made using these values as input parameters. Overall the model outputs shown by dashed lines are in good agreement with the measurements. In conclusion, the results imply that the mid-point value in the ϕ bin of the suspended sediment may be overestimated, which may give rise to the error in estimate of attenuation coefficient for the suspended sediment.

Acknowledgment
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