Measurement at 50-150 kHz of Absorption due to Suspended Particulate Matter

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Abstract: A series of experiments has been performed to study the viscous absorption by particulate matter suspended in water over the frequency range of 50-150 kHz by taking the difference in reverberation times of a volume of water with and without particles. Measured attenuation for smooth, spherical particles with a mean diameter of 40 μm agrees reasonably well with that predicted by theory for concentrations above 0.5 kg/m^3 and up to the maximum concentration tested of 2.0 kg/m^3.

INTRODUCTION

The acoustic absorption properties of suspended particulate matter in natural bodies of water are not well characterised, though there are a number of applications (e.g., naval mine-hunting sonars, acoustic Doppler current profilers) where such knowledge would be important, particularly in shallow water in the frequency range 50-300 kHz. Typical suspensions contain particles in the size range 1-100 μm where a variety of shapes and concentrations from clear water up to several kg/m^3 are possible. They are liable to produce significant absorption losses (1) which should be accounted for in propagation models.

This paper presents results from an experimental study which aims to quantify the viscous absorption associated with suspended particulate matter. Recent theoretical descriptions of the phenomenon have been published by two of the authors (1, 2), and these are compared here with experimental measurements.

EXPERIMENTAL METHOD

The reverberation time is measured for a volume of particulate-free water, T_w, and the same volume with particles suspended in it, T_S. The difference between these two values is due to the absorption by the particles, $\Delta\alpha$, which is obtained from the following expression derived from standard reverberation theory:

$$\Delta\alpha = (10 \log e^2) \frac{55.3}{8c} \left(\frac{1}{T_S} - \frac{1}{T_w} \right), \tag{1}$$

where c is the speed of sound of the fluid. The term first term on the right hand side of Eq. (1) converts the attenuation from Nepers/m to dB/m.

Because the effect of absorption is small, its affect on the reverberation time of the experimental system must be maximised relative to the other sources of absorption within the system (3). This has been achieved by using a thin-walled plastic bag which gives a boundary condition close to the ideal of a pressure release surface. Also, the location and immersion of the hydrophones is controlled so that their contribution to the total absorption is constant between tests. Previous tests have shown (4) that because of the variability in the sound field throughout the volume the reverberation time can only be measured to within ± 4%. This means that dilute suspensions (< 0.5 kg/m^3) have a high error in the value for the absorption because of the similarity in reverberation time between them and the clear-water reference signal. Higher concentrations, however, have a more acceptable error.

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RESULTS

Figures 1 and 2 show the results from a series of tests performed on 40 μm glass spheres suspended in filtered and degassed water. Figure 1 shows the reverberation time for suspensions of various concentrations as well as the clear-water reference signal. The two water traces are for calm water and stirred water, the latter being typical of the stirring required to maintain the particles in suspension. The difference between the two is generally within the 4% error band. The decrease in reverberation time as the concentration increases is obvious. Figure 2 compares the measured attenuation, normalised with respect to the particle mass concentration, to the theoretical prediction. The agreement over the range of concentrations measured is good and within the confidence intervals for the various suspensions.

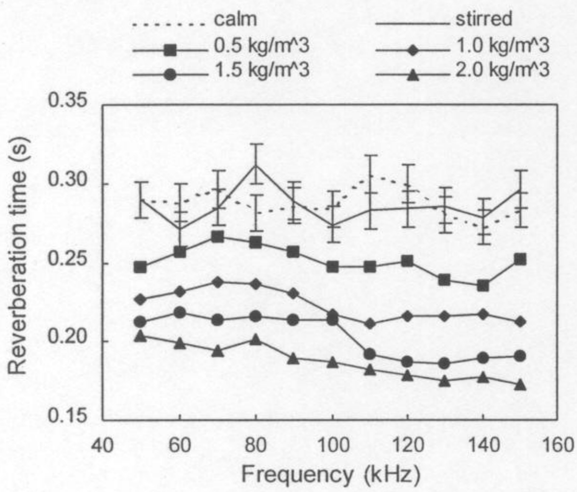

FIGURE 1. Reverberation time for calm and stirred pure water and for various concentrations of glass spheres. Error bars for water curves represent uncertainty due to measurement at a single location.

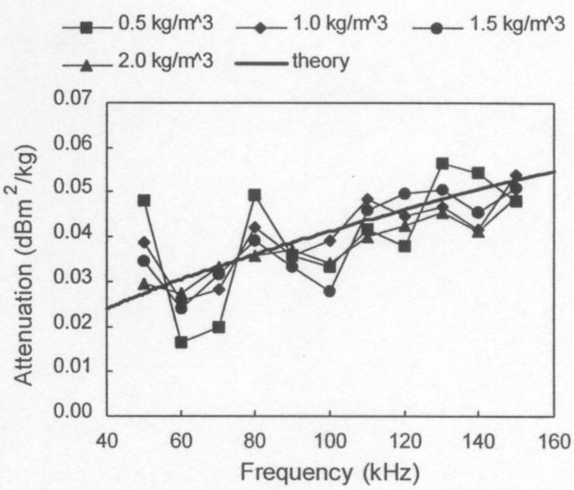

FIGURE 2. Normalised particulate attenuation at various concentrations compared to the prediction (bold line).

CONCLUSIONS

A series of reverberation tests performed on particulate-free water and water containing various concentrations of glass spheres has shown that the attenuation due to the particles is a readily measurable parameter using this technique. The measured attenuation agrees well with that predicted by theory for suspensions with a concentration greater than 0.5 kg/m^3 and improves as the concentration increases.

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