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The coherent shear wave in suspensions [Abstract]

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The coherent shear wave in suspensions

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We consider a disordered suspension of silica spherical particles in water. For particles size a few hundred nanometers and concentration (volume fraction) around 0.15 to 0.2, experiments conducted in water in the MHz range have shown [1] that the non ideal nature of the host liquid must be taken into account for the "longitudinal" coherent wave attenuation to be understood. This is done by including the waves conversion phenomena (compression / shear) in the multiple scattering model [2], while neglecting the thermal waves [3]. The model, based on the Quasi-crystalline approximation and the hole correction, provides not only the wavenumber of the "longitudinal" coherent wave that was the only one studied so far, but also that of the "shear" coherent wave. Both are obtained from the asymptotic expansion of their square, around the corresponding squared wavenumber in the absence of particles, in powers of the concentration.

We are interested here in the properties of the "shear" coherent wave, and we study its evolution with concentration c . The radius a of the particles is $0.05 \mu\text{m}$. Their physical properties, as well as those of water, are given in Table 1 of Ref. [1]. At 1 MHz, the moduli of the reduced frequencies of the longitudinal waves, $k_c a$ in the fluid, $K_c a$ in the particles, as well as that of the shear wave in the particle, $K_s a$, are negligible when compared to unity, but that of the shear wave in the fluid, $k_s a$, is not: $k_c a \simeq 2 \cdot 10^{-4} + 10^{-9}i$, $K_c a \simeq 5 \cdot 10^{-5} + 10^{-17}i$, $k_s a \simeq 10^{-1}(1+i)$, and $K_s a \simeq 10^{-4}$. Eqs. (29-32) of Ref. [2] are thus to be used, rather than the low frequency Eq. (36). These formulas are given in terms of series involving the scattering coefficients of one single particle. The figure below shows their evolution with order n .

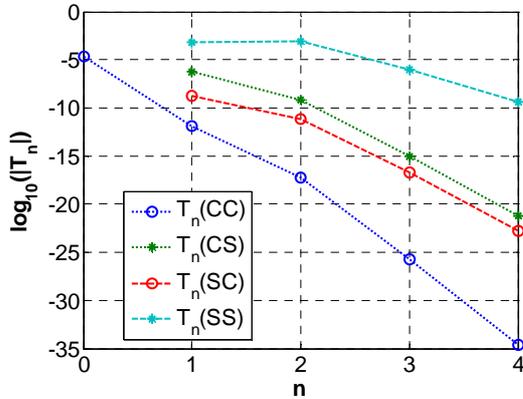


Fig. 1 Plot of the logarithm of the absolute values of the scattering coefficients versus n of a compressional wave into a compressional one (blue curve, circles), into a shear one (green curve, stars) as well as those of a shear wave into either a compressional one (red curve, circles) or a shear one (cyan curve, stars) at 1MHZ.

The order of convergence of the series over n in both the first and second order terms in concentration of the coherent shear wavenumber expansion is studied first, and we focus then on the attenuation of this coherent shear wave as a function of the concentration, and on the effective shear viscosity one can deduce here from.

[1] D.M. Forrester, J. Huang, V.J. Pinfield, F. Luppé, "Experimental verification of nanofluid shear-wave reconversion in ultrasonic fluids", *Nanoscale* 8 (10), pp 5497-5506 (2016)

[2] F. Luppé, J.M. Conoir, A.N. Norris, "Effective wavenumbers for thermo-viscoelastic media containing random configurations of spherical scatterers", *J. Acoust. Soc. Am.* 131, pp 1113-1120 (2012).

[3] V. J. Pinfield, "Acoustic scattering in dispersions: Improvements in the calculation of single particle scattering coefficients", *J. Acoust. Soc. Am.* 122, pp 205-221 (2007).