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Dispersion Technology Inc. Newsletter #19

Acoustics and Rheology

This newsletter is triggered by recent publication of our paper in the J. Chemical Physics: "Bulk viscosity and compressibility measurement using acoustic spectroscopy," 31 March 2009, Vol.130, Issue 12,
URL:
http://link.aip.org/link/?JCP/130/124519

Here is a short Abstract regarding relationship between Rheology and Acoustics.

Rheology and Acoustics are two independents sciences that study influence of mechanical stresses on solids and liquids. These sciences merge on the same subject when stress oscillates in time and wavelength of this oscillation is much shorter than system size. Description of stress-strain relationship under these conditions would require notion of wave and associated mathematical models. This link between Rheology and Acoustics has been recognized long time ago. We review these old papers and present some new results on rheology of Newtonian liquids in the recently published paper mentioned on the left column.

Rheology deals with two types of stresses - shear and extensional. Both of them maintain isochoric state of the system - liquid is considered incompressible.
Acoustic, on the other hand, is associated only with non-isochoric extensional stress. There is a special term for such stress - longitudinal stress. It is possible to introduce a "complex longitudinal modulus" that describes visco-elastic properties of a fluid under influence of longitudinal stress. It is similar to the traditional "complex shear modulus". Old thermodynamic theories yield mathematical equations that link both modules with penetration depth, parameter that characterizes distance of stress exponential decay. These equations are identical for both modules. The only difference between shear modulus (Rheology) and longitudinal modulus (Acoustics) is penetration depth. It is orders of magnitude larger for longitudinal stress than for shear stress. This makes measurements associated with longitudinal stress much simpler at high frequency on MHz range.
We also discuss two issues that present importance for Rheology but are more known in Acoustics. The first one is 160 years old Stokes's

law for sound attenuation in Newtonian fluid. Sound attenuation is important for Rheology because it is reciprocal to the penetration depth and, consequently, determines longitudinal modulus. This law offers also a simple way of testing Newtonian nature of a fluid. We illustrate this experimentally with 12 different Newtonian liquids and two non-Newtonian dispersions. Stokes's law offers also a way of measuring "bulk viscosity" of Newtonian fluid. This obscure parameter contains unique information on fluid structure, molecular "rotational" and "vibrational" degrees of freedom. We measure this parameter, together with storage modulus and compressibility for the same 12 Newtonian fluids as mentioned above.

Acoustics makes possible studying visco-elastic properties of complex liquids at MHz range, which is not accessible for traditional shear rheology. This makes it complimentary tool for rheological studies.