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Ultrasonic Characterization of Solid Suspensions in a Viscous Fluid

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This research focuses on the characterization of a random distribution of solid particles suspended in a viscous fluid. As an investigation tool, the ultrasonic waves in the MHz frequency range and their propagation through such suspensions and bringing some information on the effective properties of the suspensions. In this context, the objective of this work is to establish the relationship between ultrasonic signals and suspended particles properties, considering their geometry, dimensions, concentration and distribution.

Currently, ultrasonic methods are yet omnipresent in several fields of applications:

- Sedimentation: Evaluation of characteristics such as concentration, average particle size, particle size distribution (PSD)...
- Polluted fluids: Treatment of wastewater and regulation.
- Food products: Characterization of lipids, proteins, and other components...

Within this framework, in order to achieve those objectives, the objectives are divided in two parts:

Numerical and experimental.

The objective of the numerical study is to consolidate previous numerical results with new configurations and develop a numerical model dedicated to our case of study involving ultrasonic, suspended micro-particles, and viscous fluid. The usually considered models are involving strong assumptions such as spherical particles, low concentrations, small average wavenumber-radius product ka , constant temperature, suspensions without fluid flow. In the developed approach, such models are implemented, involving known spherical particles with a very narrow distribution density, low concentration c , viscosity η , and regulated temperature T . Using Matlab, the numerical implementation of those models and their limits are compared and discussed: ECAH, Waterman and Truell, Forester and Pinfield.

In a complementary approach, the experimental work consists in designing and constructing a practical experimental setup for ultrasonic measurements for the characterization of suspensions in a dynamic flow. In this aim, a specific instrumentation was developed to measure the effective ultrasonic properties (attenuation and velocity). The emission and reception of ultrasonic waves in the MHz frequency range was investigated for the characterization of suspended particles using a circulating pump in a temperature-regulated aquarium. Using Python, the acquisition of temporal signals was realized. A post-processing of the acquired signals was carried out using FFT, in order to determine attenuation and phase velocity as well as their frequency dependence.

As a summarize, the obtained results include:

- Numerical validation (Matlab) of a model adapted for the studied solid suspensions in a given viscous fluid.
- Development of an experimental setup and measurement protocol, outlining signal acquisition procedures (Python), FFT processing, and determination of attenuation and velocity curves as a function of frequency.
- Quantification of the influence of the flow rate, temperature, concentration and frequency.