Caractérisation ultrasonore de suspensions solides dans un fluide visqueux

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Date de la soutenance

04/06/2025 à 10:00

Lieu de la soutenance

LOMC, site Prony, 53 rue de Prony, 76600 Le Havre

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Abstract

Ultrasonic methods are widely used in various fields for the evaluation and characterization of multiphase media. Ultrasound is applied in the diagnosis of various products, including polluted fluids (wastewater treatment), food products (characterization of lipids and proteins), and suspended sediments (evaluation of concentration and particle size distribution). This research aims to establish a relationship between ultrasonic signals and particle concentration, based on the nature, shape, and distribution of the particles. To this end, an experimental setup was developed and implemented, and numerical models of multiple scattering were processed and validated. Ultrasonic measurements were carried out to characterize suspensions under dynamic flow, using specific instrumentation designed to measure effective ultrasonic properties such as attenuation and velocity. The signals were acquired and averaged under steady-state conditions using Python; signal post-processing was carried out in the spectral domain using FFT on the relevant echoes; the useful ultrasonic properties were deduced as a function of frequency via attenuation and velocity. Experiments were conducted on particles of various types: glass beads, Rilsan particles, and silt particles. The measurement conditions were varied: concentration, salinity, temperature, and flow rate. The results revealed reproducible trends: • Attenuation and ultrasonic velocity vary with concentration, in a quadratic and linear manner, respectively. • Salinity has a minimal effect on attenuation but significantly impacts velocity. • Temperature has no effect on attenuation and a limited effect on velocity. • Flow rate does not directly affect ultrasonic properties but contributes to understanding hydrodynamic processes in sediment transport or submarine flows. • Particles with non-smooth geometries, such as sediments, limit the variations in attenuation and velocity compared to smooth geometries, i.e., glass beads or Rilsan particles. • The developed experimental setup yielded reliable results, enabling the investigation of multiple influencing parameters simultaneously. Moreover, the experimental results were compared with numerical results based on McClements' work, using multiple scattering models by Lloyd and Berry, Waterman and Truell, and Ma et al. The discrepancies between experimental and numerical results prompted an advanced hydrodynamic study, conducted via finite element modeling using Comsol 2D.