Non-Invasive Diagnostics to Measure Physical Properties in High-Level Wastes

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Research Objective

This work addresses the need for a technique that can determine the rheological properties of tank wastes under processing conditions and permit the monitoring and control of slurries during transport. This task consists of applying ultrasonic Doppler velocimetry and using it to measure the viscosity of flowing waste. We will use suspensions that simulate tank waste and will work under realistic flow conditions.

The work also includes demonstration of a tomographic measurement of solids loading and velocity profiles and an investigation of the utility of this approach in estimating mass flow rate. A tomographic system uses a number of independent line-of-sight measurements to solve the problem of simultaneously measuring the solids loading and velocity profiles within the pipe. Determining mass flow rate and weight percent solids requires knowledge of the speed-of-sound as a function of loading, and questions that will be addressed include effects of the particle size and density distributions.

Finally, this work will investigate the use of ultrasonic techniques to measure sedimentation interface and rate. A tool that could result from successful demonstration could be used to monitor sedimentation progress during in-tank pretreatment and waste processing.

Research Progress and Implications

After six months into this 3-year project, a new self-contained ultrasonic Doppler velocimeter has been designed and built. It is undergoing preliminary tests of the electronics. The new unit closes the gap between a laboratory experiment and a field-deployable unit instrument for measuring velocity profiles, volumetric flow rates, and viscosities. It combines the ultrasonic Doppler velocimeter instrument, acquisition of pressure and temperature measurements, and real-time calculations of viscosity versus shear rate into one package. The package is splash- and vibration-resistant, can withstand temperatures of 100^{o}C, and is suitable for installation in the field. New capabilities have been added to make it perform without the need for operator intervention or batch lab experiments:

- It is a dual (1-MHz and 5-MHz) frequency instrument and can choose the optimal frequency automatically.

- It provides a measure of signal quality at each radial position that is used to improve data analysis.

- It measures the sound speed of the fluid concurrently with velocity measurement, automatically compensating for temperature and composition variations and eliminating the need for a new calibration when a new fluid is being metered.

- It incorporates “phase-space undersampling,” a technique that doubles the range of velocities the instrument can measure.

The new ultrasonic Doppler velocimeter system will be tested with slurry simulants in our existing flow loop. The loop has been modified to improve operation at higher flow rates with viscous materials.

We have met twice with our collaborators from University of California, Davis. Pacific Northwest National Laboratory personnel visited the University of California, Davis in December 2000. We toured their laboratory and examined the nuclear magnetic resonance instrument that will be used to validate our ultrasonic Doppler velocimeter system. We spoke to students about their research schedule and made preliminary plans for them to work at Pacific Northwest National Laboratory during summer 2001. Davis personnel visited Pacific Northwest National Laboratory in May 2001, and planning for the summer research was completed.

Planned Activities

- Slurry simulants will be chosen for pipe flow experiments – May 2001.
- We will conduct tests of the new ultrasonic Doppler velocimeter system with slurry simulants – June 2001.
- Student research will be conducted using the ultrasonic Doppler velocimeter system – summer 2001.
- A low-resolution ultrasonic tomography system (basically two copies of the ultrasonic Doppler velocimeter system) will be developed for detecting settling in pipe flow of slurries – fall 2001.
- Experiments to determine the critical settling velocity for slurries in pipe flow will be conducted - winter 2002.
- Nuclear magnetic resonance experiments will be conducted to determine the critical settling velocity for slurries in pipe flow (done at University of California, Davis in parallel with Pacific Northwest National Laboratory's ultrasonics-based measurements) – winter 2002.