SC-11

EMSP
Environmental Management Science Program
Project Summary Fact Sheet • April 2000

ENGINEERING SCIENCE AND GEOPHYSICS

ENGINEERING SCIENCE PROJECTS INVESTIGATE FUNDAMENTAL PROPERTIES OF MATERIALS AS WELL AS INFORMATION NEEDED FOR PROCESS DESIGN

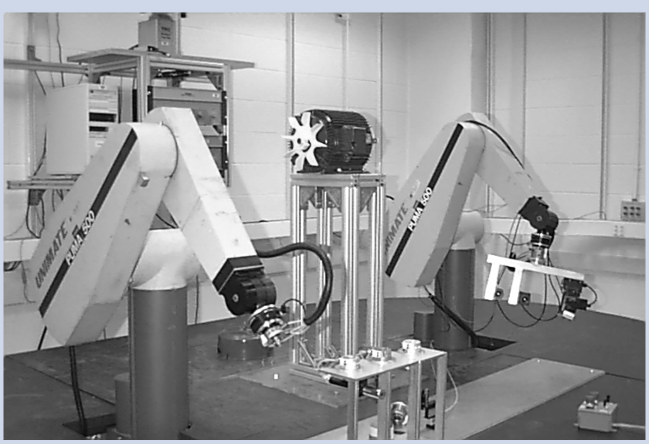
An EMSP project related to geophysics involves an exploration of seismic methods for the characterization of some bulk physical properties of the materials in underground storage tanks. The source would be placed on the surface above the tank, and an array of hydrophones would be placed in the liquid observation well in the tank.

An engineering science project that addresses needs in the deactivation and decommissioning area involves advances in robotics for disassembly of complex systems that are too highly contaminated for direct contact with workers. The goal is to develop a system that would allow the operator to use virtual reality operations to give directions to the teleoperated robotic device.

Projects related to high-level waste remediation include:

- An experimental and computational investigation of the potential consequences of an extended failure of the ventilation and purging systems in a high-level waste tank. Previous models for enclosure fires were not adequate for assessing the potential for accumulation of pockets of oxygen and flammable gases in a tank.
- Examinations of some fundamental issues related to the development of sensors for the viscosity and density of slurries from waste tanks. These included examinations of nuclear magnetic resonance imaging and ultrasonic velocimetry for an on-line slurry viscosity sensor and an acoustic probe to measure the solids content in slurries.
- A study of the magnetic properties of simulated tank sludge and flyash samples to determine if magnetic separation techniques would be useful for removing deleterious materials from a vitrification feed stream.

A project with potential applications to treatment of mixed waste involves an investigation of more efficient plasma processes for the destruction of volatile organic compounds.



Robotics
A Clemson University project (55052) is involved in developing semi-autonomous teleoperated robotics. This photo shows a dual arm arrangement in the lab with end-effector-mounted computer vision sensing package (right arm) for virtualization of motor before disassembly.

PROBLEMS/SOLUTIONS

- It is essential to verify that slurries can be successfully transferred from high-level waste tanks, and measurements of flow properties will be needed to aid the design of equipment for this purpose. Two EMSP projects have investigated some basic science issues related to development of slurry monitors.
- Disassembly of highly contaminated objects requires sophisticated robotic devices. An EMSP project is attempting to develop teleoperated robotic devices for which the operator input is in the form of virtual reality operations.
- Measurements of the fractions of solid and liquid phases present inside high-level waste tanks are difficult and expensive. One project has explored the use of geophysical techniques that may be able to determine these quantities with minimal invasive procedures within the tanks.

ANTICIPATED IMPACT

- A thorough understanding of the generation and venting of hydrogen is particularly important for safe operation of the 177 tanks at Hanford (average capacity over 700,000 gallons each) and the 49 tanks at Savannah River (average capacity over 1,100,000 gallons each). An EMSP project has explored the possibility of the formation of pockets of flammable mixtures of gases that could result from an extended failure in the ventilation system in a tank.
- Oxides of iron and related elements can severely degrade the properties of the glass used for immobilization of wastes, so failure to remove these materials from the immobilization feed stream could result in poor glass performance or low waste loadings in the glass. A joint effort at two U.S. Department of Energy (DOE) labs and two universities has explored the magnetic properties of tank sludge and flyash surrogates to determine if magnetic separations of these oxides are possible.

A Plasma Process for the Destruction of Volatile Compounds

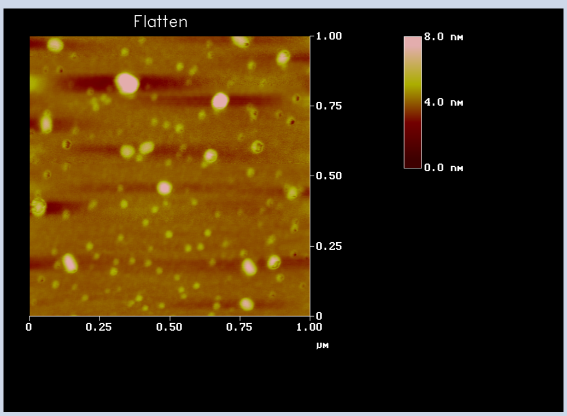
The ORNL group (54973) has investigated the use of a more efficient plasma process for the destruction of volatile organic compounds. They have found that electron attachment to electronically excited states of molecules is much more probable than for ground state molecules. They have produced metastable states of rare gases in a plasma and then observed the results of energy transfer and electron attachment to the target molecules in the afterglow of the plasma. The reaction in the glow discharge did not yield any gaseous products other than the rare gases that were used in the gas mixtures, and only particulates were observed. The glow discharge is maintained between a cylindrical anode and cathode with a pressure in the range of 1 to 10 torr and a flow rate of a few standard liter per minute in the experimental reactor.

Robotics

The Clemson University project (55052) involved developments in the area of semi-autonomous teleoperated robotics. A dual-manipulator mobile work cell is to be supported by computer vision, virtual reality, and advanced robotics technology. Research on these three subsystems proceeded separately, but integration into a complete system is currently being explored. The intended operator input is to be in the form of virtual reality actions as opposed to joystick or manually teleoperated devices, so the operator would have the experience of being at the work site. The goal is to be able to use the system for disassembly of complex systems that present excess hazards for direct worker contact.

Mechanisms for the Formation of Flammable Gas Mixtures in Tanks

The University of California – Berkeley project (54656) involved both experimental and modeling studies to explore the consequences of failure of ventilation and purging systems that prevent the generation of dangerous mixtures of flammable gases and oxygen. Experimental studies with small tanks were designed to simulate buoyancy-driven flows of air into the tanks through the ceiling ports, and a laser-based technique was used to measure the transient density changes. They also investigated heat and mass transfer from a heated surface in a cylindrical enclosure along with purge jet injection to simulate these phenomena in a high-level tank. Mixing in tanks is generated by buoyant jets arising from radiolytic generation of gases, temperature or concentration gradients, heat transfer at the walls or cooling tubes, and liquid-vapor interfaces. Previous models developed for enclosure fires were not considered adequate for assessing the potential for accumulation of high-concentration pockets of oxygen and flammable gases in the tanks, and more general computational models were being developed and compared to the results from the experimental simulations.



Plasma Process for Destroying Volatile Compounds
An ORNL group (54973) has investigated using a more efficient plasma process to destroy volatile organic compounds. This atomic force microscope image shows the dust particles from an Ar/Benzene glow discharge.

Measurements of the Properties of Slurries

Retrieval of high-level tank contents for separation and treatment will require pumping slurries through pipes. Inadequate mixing with water may result in plugged pipes, but excess water will unnecessarily increase the volume of the material requiring downstream processing. There have been extensive efforts by others to develop slurry monitors, and the goal of the University of California – Davis/PNNL project (54890) was to examine nuclear magnetic resonance imaging and ultrasonic Doppler velocimetry for on-line sensors for the viscosity of dense slurries. The velocimetry technique was based on simultaneous tomographic pulse-echo ultrasonic flow velocity and time-of-flight speed of sound measurements. These studies concentrated on systems with known properties and had not yet been applied to the complex mixtures typical of waste-tank slurries. Other modeling work was aimed at understanding the structure of concentrated suspensions of particles with variable sizes.

The goal of the Syracuse University/PNNL project (55179) was to develop an acoustic probe to permit measurements of solid content in gas-liquid-solid waste slurries in high-level tanks. The attenuation of an acoustic signal of a certain frequency in a suspension of particles can be calculated if the attenuation due to particles of each possible radius and the number density of such particles is known. This project has involved both experimental and computational aspects of this problem, with the focus on the use of measured attenuations as a function of frequency to obtain the distribution of particle sizes and the total solid number density. The attenuation as a function of volume fraction of the particles can go through a maximum, so the same attenuation can be obtained at two different volume fractions for a given frequency. They have found, however, that the phase speed changes monotonically with the volume fraction, so future work on the probe will include phase speed measurements as well as studies of three-phase systems with unknown bubble size distributions.

Characterization of Underground Storage Tanks Using Seismic Measurements

The MIT project (55141) explored potential applications of seismic measurements in which a source is placed on the surface outside a tank and a hydrophone string is placed in the only liquid observation well inside the tank. Modeling studies for a tank with a single fluid layer were found to be in fairly good agreement with scaled measurements on small tanks. The normal modes were found to be especially useful even when the vertical array of hydrophones is not on the center line of the tank, which would be the case with many Hanford tanks. It was also shown that measurements in a tank should be made at high frequencies to obtain information on properties such as the layering, fraction of solid and liquid phase, and presence of interstitial gas in the material inside tanks. The basic studies completed so far were necessary before attempting these more complex tasks.

Magnetic Separation of Vitrification Feeds

Transition metal (iron, cobalt, nickel) oxides may cause defects in glass that reduce its usefulness for long-term storage of radionuclides. The objective of the ANL/WSRC/University of South Carolina/University of Texas project (55294) was to examine the potential utility of magnetic separation techniques to remove deleterious materials from a vitrification feed stream. They prepared several tank sludge and flyash surrogates to match the chemical composition of wastes that are projected for vitrification. Flyash was found to contain many particles in the sub-micron size range, so these materials present material handling problems for a pre-treatment system. However, it was found that a high-gradient magnetic separation was useful for a Hanford sludge surrogate. Current work involves the identification of fundamental magnetic properties of the waste materials along with the development of models to use these properties for the design of optimal magnetic separation techniques.

Project Teams

Lead Principal Investigator (Award Number)

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- Clemson University
  PI: Robert J. Schalkoff (55052)
- Massachusetts Institute of Technology
  PI: M. Nafi Toksoz (55141)
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