363f Effect of Jet Pulsing on the Mixing of Non Newtonian Fluid in Storage Tank

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Abstract

To retrieve radioactive waste from a tank for treatment and disposal, jet mixer are used to stir radioactive sludge, salt cake, and supernatant liquid. This approach produces slurry that can be easily removed from a tank. During the waste retrieval process, complex interactions occur among waste mixing, chemical reactions, and associated Rheological phenomena. To determine safe and cost-effective operational parameters for waste retrieval, decisions must rely on new scientific knowledge to account for physical mixing of multiphase flows, chemical reactions, and waste Rheological characteristics. Thus, it is important to investigate the interactions between the Rheological features and mixing processes. The objective of this study is to investigate the effect of jet pulsing on the mixing of non-Newtonian fluids in storage tank using laser diagnostic techniques. Particle Image Velocimetry (PIV) technique with high spatial and temporal resolution is used in this study to measure the flow pattern and mixing properties of non-Newtonian fluid in storage tank. The study focuses on the effects of fluid Rheological characteristics (viscosity, shear stress, shear rate), jet characteristics (exit velocity, Reynolds number), and jet pulsing conditions (frequency) on the mixing of non-Newtonian fluid flows. The results presented in this paper will show (1) the effect of jet pulsing frequency (f = 1 – 120 Hz) on the mixing process of non-Newtonian fluids and (2) the pulsing conditions leading to the optimum mixing (efficient distribution of the feed into the bulk tank volume and fluid velocity magnitude used to maintain solids in suspension and mobilize sludge from the tank floor). The results obtained in the course of this study are used as an assessment tool to support decisions made during waste retrieval operations.

Experimental Setup

In tank mixers are used to mix tank contents by circulating the process fluid through a pump and then re-injecting it via a jet mixer. The advantage of this arrangement is that it increases the bulk mixing efficiency and considerably improves small-scale mixing effects that are often associated with chemical reactions. The schematic diagram of the experimental setup is shown in Figure 1. The storage tank is 200 mm in diameter and 100 mm high. The storage tank is made of high-quality Plexiglas to allow the acquisition of good PIV images. The liquid is a non-Newtonian fluid of aqueous non neutralized Carbopol solution. This solution is used to simulate the Rheologic characteristics of the original sludge in the waste tank (non-Newtonian fluid). Most of the sludge wastes exhibit non-Newtonian, shear thinning behavior (i.e., slurry viscosity decreases with strain rate). The Rheological characteristics of the Carbopol solution are represented by $t = to + K g^{n}$, where t is the shear stress, K is the consistency factor, g is the shear rate (1/s), and n is the behavior index (See Fig. 2). The solution is prepared by dispersing X ppm (by weight) of Carbopol resin in deionized water. Five concentrations are tested in this study: X = 200, 400, 600, 800, and 1000 ppm. The viscosity of the fluid increases with the concentration of the solution (See Fig. 2). A pump is used to re-inject a volume flow rate (Qv = 50 to 250 ml/s) in the tank through an injector. The injector nozzle is 4 mm in diameter and will be positioned at the bottom of the tank. A solenoid valve is used to control the frequency (1, 5, 10, 20, 40, 80, 120 Hz) of the pulsed liquid jet injected inside the tank. A wave generator is used to send the control signal to the valve.

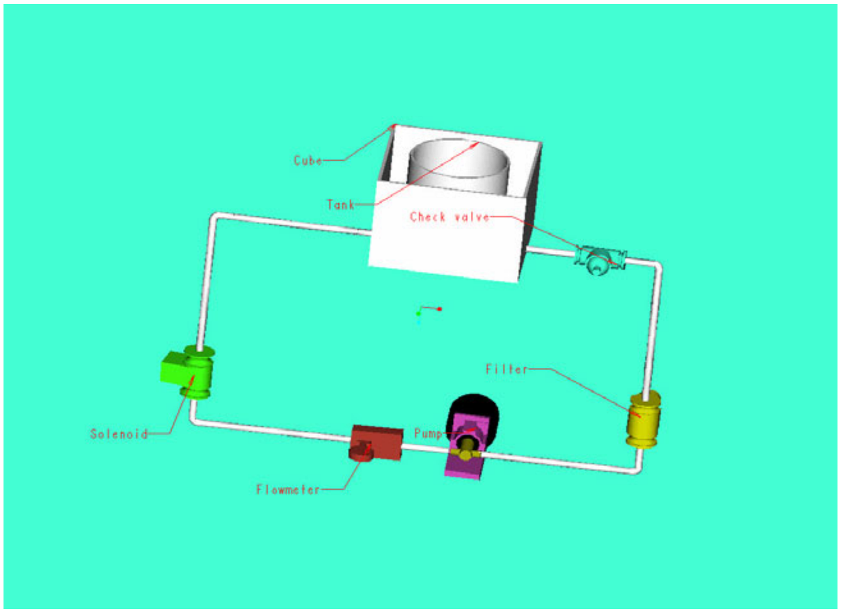

Figure 1. Experimental setup.

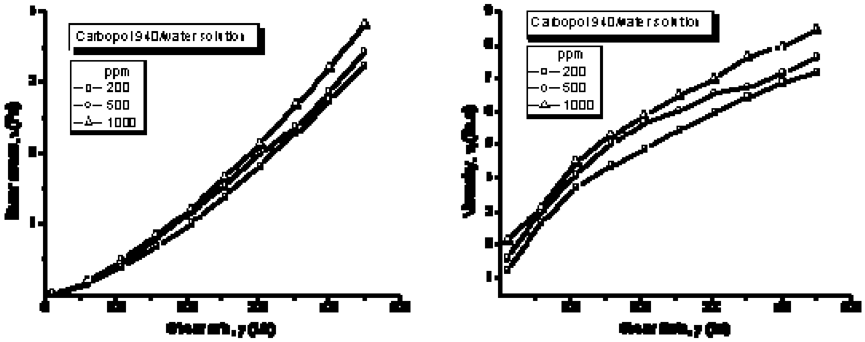

Figure 2. Rheological characteristics of Carbopol/water solution

Velocity Measurements Using Particle Image Velocimetry

The PIV system shown in Figure 3 is used to obtain the velocity vector plots containing both velocity amplitude and flow direction for the whole visualized flow field with high accuracy and high resolution. The PIV system consists of an illumination system, a video camera, a vector processing unit, and a personal computer with software to control the entire system and analyze data. The laser sheet is positioned vertically (as shown in Figure 3) to get the velocity field along the entire height (h = 0 to 100 mm) of the storage tank and horizontally at the position of jet injection (h = 15 mm). The PIV system measures the displacement of individual particles in a two-dimensional illuminated plane inside the flow. The cross-correlation technique is used for the determination of the velocity vectors. Two short laser pulses from an argon ion laser are fired with a known time separation to illuminate the seeding particles embedded in the solution. The beam from the continuous wave laser is chopped into pulses using an electro-optical shutter. A double-image camera is used to record images of the illuminated section. The camera contains a video format CCD chip and special electronics for fast inter frame acquisition of two sequential images. A 768 x 484–pixel image size is used to capture the images. The images will then be transferred to a PIV 2000 processor via the digital connector and to a host computer for data processing and analysis. Polyamide seeding particles are used for the velocity measurements. These particles have a mean particle diameter of 20 mm and a density of 1.03 g/cm^3. These seeding particles are suitable because the flow velocity is considerably higher than the particle settling velocity.

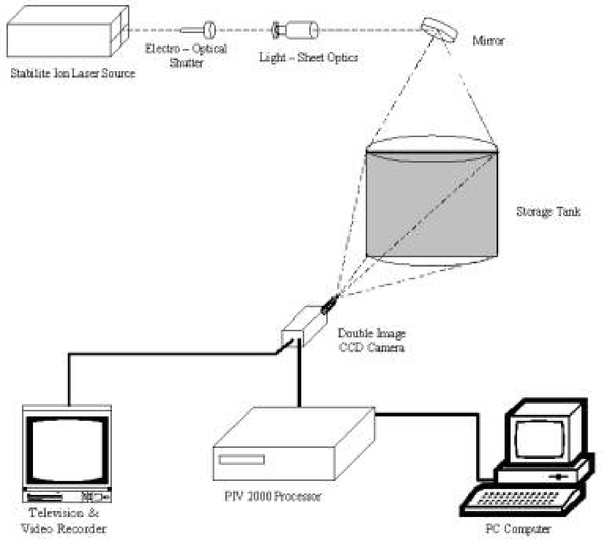

Figure 3. Particle Image Velocimetry System.