STUDIES ON HYDRODYNAMICS AND MIXING IN BUBBLE COLUMNS EMPLOYING NON-NEWTONIAN FLUIDS

By

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CERTIFICATE

This is to certify that the thesis entitled,"STUDIES ON HYDRODYNAMICS AND MIXING IN BUBBLE COLUMNS EMPLOYING NON-NEWTONIAN FLUIDS" being submitted by Mr. Md. Wasiful Haque to the Indian Institute of Technology, Delhi for the award of the degree of 'DOCTOR OF PHILOSOPHY' is a record of the bonafied research work carried out by him. Mr. Md. Wasiful Haque worked under our guidance for the submission of this thesis which to our knowledge has reached to requisite standard.

The thesis or any part thereof has not been submitted to any other University or Insitution for the award of any degree or diploma.

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ABSTRACT

Experimental data are reported on the gas holdup in 0.10m, 0.20 m, 0.38 m and 1.0 m diameter bubble columns employing water and highly viscous pseudoplastic CMC solutions. Transient conductivity or pH measurements were carried out to measure mixing time. Nine different gas sparger designs were employed to study the possibility of optimum sparger design in a 1.0 m diameter bubble column. Single bubble size and its rise velocity through a pseudoplastic non-Newtonian (CMC) liquid pool were studied by a cine photographic technique with a 16 mm high speed camera. The major results from the above studies are :

- A flow transition chart has been developed to predict the flow regime for highly viscous pseudo-plastic non-newtonian systems in bubble columns for a wide range of operating parameters. Effective critical viscosity at the transition from churn-turbulent to slug flow regime for different column diameters is also predicted.
- A correlation for the gas holdup in the churn turbulent regime has been presented covering a wide range of operating parameters as

$$\varepsilon = 0.171\, U_G^{0.6} \mu_{eff}^{-0.22} D^{-0.15}$$

with a standard deviation of 0.01 for $U_G \geq 0.03\ ms^{-1}$ and $0.10\ m \leq D \leq 1.0\ m$. This will be useful to design industrial size bubble columns treating viscous pseudo-plastic non-Newtonian solutions.

- The inviscid liquid circulation model has been found to be applicable for non-Newtonian systems as well in large diameter bubble columns. Although the liquid employed is viscous, it is shown that the inviscid circulation model explains the data extremely well.
- A new method has been developed to obtain the volume-to-surface mean bubble diameters using the estimated isolated bubble rise velocities from bubble column experiments.
- The drag coefficient relation of Hirose and Moo-Young is found to be valid for single rising bubbles in CMC solutions. The isolated bubble rise velocity reaches a constant value of about 0.30 m/s for a bubble size range of 10-18 mm for CMC concentrations studied here.
- Experimental mixing time data have been reported in bubble columns employing CMC solutions with different ratios of clear liquid height to diameter. An expression has been developed to predict the liquid circulation time required for complete mixing. The liquid mixing behavior is explained in terms of the average liquid circulation velocity. The equivalent path lengths for lag time, bulk mixing time and diffusion time are found to be (0.5D+H), (0.5D+H) and 5D respectively. A mathematical expression has been derived to predict the mixing time.

- Optimization of gas sparger design with respect to gas holdup and mixing time data is possible.
- Standard graphs and design equations have been developed which enable quick design and evaluation/optimization of continuous or semi-batch bubble columns treating Newtonian and non-Newtonian liquids.

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