Topology study of three-phase flow through fast-response capacitive sensing

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Advisor: Prof. Assoc. Oscar Rodriguez

São Carlos - JUNE 27th, 2013
New WMS

- To the Vertical Line:
  - 16x16 wires, 50.8 mm internal diameter
    - Wire diameter: 0.05 mm
      Intrusiveness Factor: 3.12%
    - Wire diameter: 0.1 mm
      Intrusiveness Factor: 6.20%
    - Square Shape
New WMS

To the Horizontal Line:
• 8x8 wires, 26 mm internal diameter
  o Wire diameter: 0.05 mm
    Intrusiveness Factor: 3.05%
  o Wire diameter: 0.1 mm
    Intrusiveness Factor: 6.05%
  o Square Shape

• 16x16 wires, 26 mm internal diameter
  o Wire diameter: 0.05 mm
    Intrusiveness Factor: 3.05%
  o Square Shape
New DAQ Boards

▶ Coupling Board
  - Allows use the new computer with the previous Rx (signal conditioning) boards. Protect the new equipment.

▶ Analog Multiplexer Board
  - Allows use a bigger area of the planar wire-mesh sensor
  - 64 inputs x 16 outputs
New DAQ Boards

- Synchronization Board
  - Allows have two modes of acquisition:
    - 2 - 8 x 8, simultaneous acquisition.
      Max. 4 kf/s with the NI-6224
    - 1 - 16 x 16
      Max. 2 kf/s with the NI-6224
New DAQ Boards

- **Tx Board (3th version)**
  - New improvements
  - 16 channels
  - Synchronization

- **Rx Board**
  - New improvements
  - 16 channels
  - Three-phase
Papers

- Submitted
  - “APPLICATIONS OF WIRE-MESH TOMOGRAPHY IN MULTIPHASE FLOWS”
    - H. F. Velasco-Peña, O. M. H. Rodriguez
  - Submitted to Flow Measurement and Instrumentation
  - Review of 157 papers. Includes: Operating Principle, Sensor Geometries, Types of Measurements, Limitations and Disadvantages, Validation, Applications
Submitted

“EXPERIMENTS WITH A WIRE-MESH SENSOR FOR STRATIFIED AND DISPERSED OIL-BRINE PIPE FLOW”

Rodriguez, I. H.; Velasco Peña, H. F.; Bonilla Riaño, A.; Henkes, R.A.W.M.; Rodriguez, O. M. H.

Submitted to International Journal of Multiphase Flow

Two-phase oil-water flow, using mineral oil (having 830 kg/m³ density and 7.5 mPa s viscosity) and brine (1073 kg/m³ density and of 0.8 mPa s viscosity).

15 m long horizontal steel pipe, with 8.28 cm internal diameter

Measurements of the holdup and of the cross-sectional phase fraction distribution were obtained for stratified flow and for highly dispersed flow, including the interface shape and water height.

Uses a circuit for capacitive measurements that is adapted to conductive measurements, using several mixture permittivity models.

The experiments were conducted in the multiphase-flow test facility of Shell Global International B.V. in the Netherlands.
Papers

Submitted

“EXPERIMENTS WITH A WIRE-MESH SENSOR FOR STRATIFIED AND DISPERSED OIL-BRINE PIPE FLOW”

Adaptation

\[ \hat{\kappa}_x = \kappa_x - j \frac{\sigma_x}{\omega \kappa_0}, \]

\[ a(i, j) = \frac{2 \left( V_H(i, j) - V_L(i, j) \right)}{\ln(\omega^2 \kappa_0^2 \kappa_H^2 + \sigma_H^2) - \ln(\omega^2 \kappa_0^2 \kappa_L^2 + \sigma_L^2)}, \]

\[ V_L(i, j) \ln \left( \frac{\kappa_H^2}{\omega^2 \kappa_0^2} + \frac{\sigma_H^2}{\omega^2 \kappa_0^2} \right) - V_H(i, j) \ln \left( \frac{\kappa_L^2}{\omega^2 \kappa_0^2} + \frac{\sigma_L^2}{\omega^2 \kappa_0^2} \right), \]

\[ b(i, j) = \frac{\ln(\omega^2 \kappa_0^2 \kappa_H^2 + \sigma_H^2) - \ln(\omega^2 \kappa_0^2 \kappa_L^2 + \sigma_L^2)}{\ln(\omega^2 \kappa_0^2 \kappa_H^2 + \sigma_H^2) - \ln(\omega^2 \kappa_0^2 \kappa_L^2 + \sigma_L^2)}. \]
Papers

- Submitted
  - “EXPERIMENTS WITH A WIRE-MESH SENSOR FOR STRATIFIED AND DISPERSED OIL-BRINE PIPE FLOW”
  - Adaptation

![Graph showing oil holdup fraction comparison]
Papers

- Submitted
  - “EXPERIMENTS WITH A WIRE-MESH SENSOR FOR STRATIFIED AND DISPERSED OIL-BRINE PIPE FLOW”
  - Interface Height

Generalized Logistic Function or Richard’s Curve

\[
\varepsilon_f(h) = A + \frac{K}{\left(1 + v \cdot e^{-B(h-h_a)}\right)^{1/v}}
\]

<table>
<thead>
<tr>
<th>Two-Fluid Model</th>
<th>ARE (%)</th>
<th>Dev (%)</th>
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<tr>
<td>Taitel &amp; Dukler, 1976</td>
<td>26</td>
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<td>Trallero, 1995</td>
<td>10</td>
<td>10</td>
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<td>Rodriguez and Baldani, 2012</td>
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Accepted for poster presentation

“Capacitive Wire-mesh Sensor Measurements in Oil-water Flow”

Iara H. Rodriguez, Hugo F. Velasco P., Adriana Bonilla Riaño, Oscar M. H. Rodriguez

Submitted to 10th International Conference on Heat Transfer, Fluid Mechanics and Thermodynamics (HEFAT2014)

A capacitive wire-mesh sensor was applied to viscous-oil in water dispersed flow in a transparent acrylic section of 26-mm-i.d. and 12-m-length.

Twelve mixture permittivity models were applied to calculate the oil volumetric phase fractions in order to compare with QCVs. In two models the relation is modified as function of a variable parameter.

Oil phase fraction average relative error as a function of the parameter $u$ (Maxwell-Garnett model).
Thank you!

Special thanks to Oscar, Adriana, Iara, Luis, Helio, Roberto e Jorge.