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Wet gas flow metering technique using a venturi with conductance sensors

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Design and build a digital liquid level sensor to measure the liquid film thickness at the inlet of the Venturi in annular flow.

Design and build three separate conductance electronic circuits for:
- Two upstream ring sensors, designed to measure the film velocity by cross correlating signals between two sensors at the inlet.
- The digital level sensor, designed to measure the liquid film thickness in annular flow.
- The throat ring sensor, designed to measure the gas volume fraction at the throat.

To use a data acquisition device to integrate the system measurements and to control the operation of the device:
- The throat conductance sensor.
- The digital level sensor.
- The inlet conductance sensors.
- The differential pressure sensors.

THE MEASUREMENTS

What measurements we need to make and how these measurements will be integrated into mathematical model to give the liquid and gas flow rates:
- Measuring the film velocity in wet gas flow.
- Measuring the film thickness $\beta$.
- Measuring the gas volume fraction at inlet $\alpha_1$.
- Measuring the water conductivity $\sigma_w$.
- Measuring the gas volume fraction at the throat $\alpha_2$.
- Differential pressure in wet gas flow $\Delta P$.

We make the above measurements and combine them to enable the gas flow rate in annular flow to be determined and the mass flow rate of water in the film using the equation 1 and 2 respectively.

DESIGN OF THE CONDUCTANCE VENTURI METER

A new Venturi with conductance sensors was designed and constructed to determine the gas flow rate.

### TECHNIQUE

**Measuring the film velocity in wet gas flow**

Measured by cross-correlating the conductance signals between two sensors at the inlet of the Venturi, using the conductance electronic circuits of the upstream ring sensors.

**The film thickness measurements**

Using a digital level sensor at the inlet of the Venturi (upstream).

**The Gas volume fraction measurement**

From the conductance circuit we know feedback resistance and the excitation voltage.

The measurement equation is $V_1 = V_2 R_w \sigma_w K(\alpha_1)$, we therefore have $K(\alpha_1) = \frac{V_2}{V_1 R_w \sigma_w}$ and $\sigma_w = \frac{V_2}{K(\alpha_1) - V_1}$.

The cell constant $K(\alpha_1)$ vs $\alpha_1$ gas volume fraction at the inlet.

**The water conductivity measurements**

We now need to know how the conductivity sensor will be used with the digital level sensor in a real application to find the water conductivity.

**The Gas volume fraction measurement at the throat**

The measurement of the gas volume fraction at the throat relies upon knowing the liquid conductivity under actual flowing conditions.

We have $K(\alpha_2) = \frac{\sqrt{V_2 h_t K_w V_1}}{\sigma_w}$, $\alpha_2$ vs $K(\alpha_2)$.

**Differential pressure in wet gas flow**

As in the figure the differential pressure will be measured by the $\Delta P$ cell.

\[
\Delta P_{\text{in}} = (P_1 - P_2)
\]

**Measuring the gas flow rate in annular flow**

We make the above measurements, to combine them to enable the gas flow rate in annular to be determined using the equation $m = C_A \left( \frac{\Delta P}{A} \right) \left( \frac{A_1 A_2}{A_1 A_2} \right) \left( \frac{1}{\rho_1} - \frac{1}{\rho_2} \right)$.

**Measuring the gas flow rate in annular flow**

The mass flow rate of water in film can be obtained from the following equation.

\[
\dot{m} = \frac{Q}{\rho_w}
\]