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Computing and Engineering

Systems Engineering

Research Group

Novel Multi-Electrode Electromagnetic Flow Meter

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University of HUDDERSFIELD

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BACKGROUND

Electromagnetic flow meters have been used successfully in many industries to accurately measure the mean liquid velocity in axis-symmetric single phase flows of conducting liquids.

A conventional electromagnetic flow meter measures a potential difference which is induced between two electrodes when the conducting fluid flows through a uniform magnetic field which is applied perpendicularly to both the flow direction and to a line joining the electrodes. The benefits of using a conventional electromagnetic flow meter are:

- Low pressure drop
- Fast response to the changes in the flow velocity
- Can be used with a low conductivity fluids (down to 0.5µS/cm)
- Temperature, density, pressure and viscosity have no influence on the measurement

OBJECTIVES

A conventional electromagnetic flow meter detects the potential voltage differences between two electrodes, located at d and d' shown in figure 3. The main objective of the current research is design a novel multi-electrode electromagnetic flow meter that can measure the liquid velocity profile.

To do this (i) a uniform magnetic field in the pipe cross section is required; (ii) the induced voltages between *N* electrode pairs are measured; (iii) Using electromagnetic weight functions a matrix equation is solved to give the liquid velocity in *N* distinct regions in the flow cross section.

DESIGN of a UNIFORM MAGNETIC FIELD in the FLOW CROSS SECTION

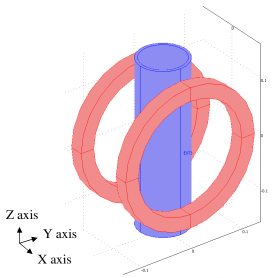

Figure:1 Simulation Model

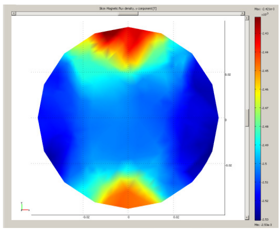

Figure:2 Magnetic Flux Density

The distribution of the magnetic flux density for the multi-electrode Electromagnetic flow meter uses a Helmholtz coil, shows in figure 1. The system was simulated using 'COMSOL Multiphysics' to achieve the optimised magnetic flux density distribution shown in Figure 2. A real device has since been built based on the optimised design shown in figure 4

MULTI-ELECTRODE ELECTROMAGNETIC FLOW METER DESIGN

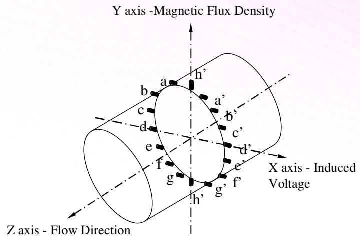

Figure:3 Schematic diagram of multi-electrode electromagnetic flow meter

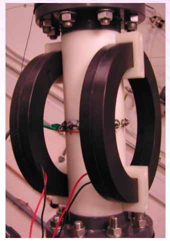

Figure:4 Novel multi-electrode electromagnetic flow meter

The novel electromagnetic flow meter includes sixteen electrodes equally spaced around the internal circumference of an 80mm diameter Delrin pipe.

In an initial experiment these electrodes are paired according to a-a', b-b' etc with the line between each of the 7 electrode pairs lying normal to both the direction of the imposed magnetic field and the fluid direction.

A magnetic field of 40 Gauss was applied using the Helmholtz coils and the induced potential difference between each of 7 electrode pairs was measured.

WEIGHT FUNCTION THEORY and PIXEL SEPARATION METHOD

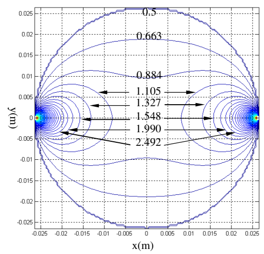

Figure:5 Contours of weight function when electrodes are located at y = 0

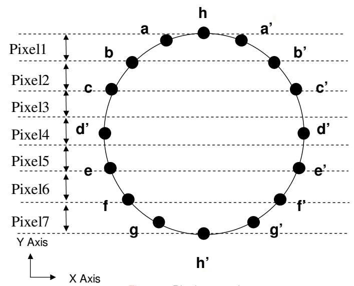

Figure:6 Pixel separations

Figure 5 shows the well known 'weight function' distribution for a single electrode pair in a conventional electromagnetic flow meter. In the present investigation the weight functions relating the flow velocity in each of the 7 pixels (see figure 6) to the potential difference measured between each of 7 pairs of electrodes (see figure 6) are required and were obtained using COMSOL Multiphysics (49 weight functions in total).

The weight function value indicates the relative contribution of the flow at a given point in the flow cross section to the potential difference between a given pair electrodes. [NB: The weight function contours given in figure 5 shows that for a conventional electromagnetic flow meter the effect of the flow velocity is strong near the electrodes and decreases with increasing distance away from the electrodes].

EXPERIMENTAL ORIENTATION

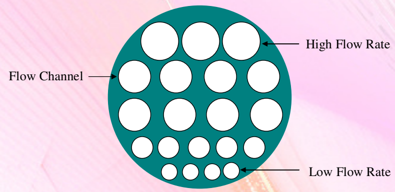

Figure:7 Tube Bundle

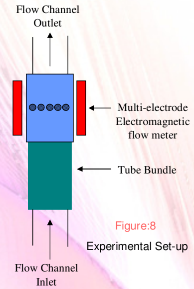

Figure:8 Experimental Set-up

Tube bundle is another type of flow conditioner, which helps to generate a known velocity profile to validate the multi-electrode electromagnetic flow meter measurement.

VELOCITY RECONSTRUCTION

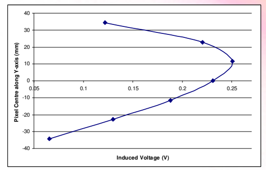

Figure:9 Voltage distribution from seven electrode pairs

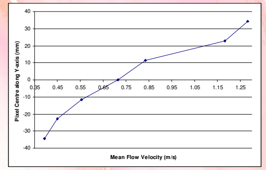

Figure:10 Mean flow velocity in pixels

Using the relationship $[V]=\frac{\pi a}{2B}[WA]^{-1}[U]$, the mean flow velocity in each of the seven pixels was calculated. [NB: where V is the velocity matrix (see figure10), W is the weight function matrix, A is the pixel area matrix and U is the potential difference matrix (see figure 9)

CONCULSION

The multi-electrode electromagnetic flow meter shows considerable promise as a means of measuring the local velocity distribution in highly non-uniform single phase flows. Recent work undertaken at University of Huddersfield also shows that the device can be used to measure the local water velocity distribution in multiphase flows.

FUTURE WORK

- To increase the spatial resolution of the measurement form 7 pixels to 120 pixels in the flow cross section
- To improve the accuracy of the velocity profile obtained from the matrix inversion algorithm.
- Apply the electromagnetic flow meter to measure the water velocity distribution in 'water continuous' multiphase flows (e.g. oil-in-water and solids-in-water flows).
- Use the electromagnetic flow meter in conjunction with an EIT system to measure the volumetric flow rates of both phases in two phase flows.
- Investigate electrode material which minimise voltages generated due to electrochemical effects.
- Investigate the effects of dimensional errors in the flow meter on the values of the weight functions.
- Investigate alternative matrix inversion methods such as the conjugate gradients method.