Image Reconstruction of micro particles concentration in a microchannel using electrical computed tomography

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In investigating a microchannel, understanding regarding dispersion reaction are need to be acquire first down to the view point of multiphase flow dynamics. Usually, various measurements methods and in-depth analysis are necessary to understand thoroughly the inside reaction occurs in this kind of system. A novel microchannel system is designed for electrical computed tomography that embedding three dimensional electrodes distributed around in five cross sections. Electrical computed tomography is visualized into a cross-sectional image representing the distribution of density in two-phase flow. Therefore, the application of electrical computed tomography can consider in the microchannel. In this study, we measure the particle distribution in the microchannel and making the 3D image result using electrical computed tomography. We discuss how to simulation of the cross-section image in microchannel.

1. Introduction

Fluid flow in micro channels has been motivated by their various applications such as medical and biomedical use, computer chips, and chemical separations [1]. To fabricate micro channel devices, micro channels have need of the inside of micro channel’s reaction and measurement of the particle concentration. Many studies have been carried out a measurement of the particle concentration on micro channel. Especially, electrical tomography is the availability of a complete flow image containing concentration distribution within vertical cross-sectional image plane in dense two-phase flow. Also, electrical impedance tomography is characterized by good time resolution and low cost, it has obvious advantages in the application to the visualization of multiphase flow. EIT is to evaluate conductivity distribution inside the examined object by measuring the voltages between electrodes placed on its surface. In this study, we discuss how the reconstruction of cross-section solves the impedance tomography in the multiphase flow.

2. Experiment

When electrical currents \( I_l (l=1,2,\ldots,L) \) are injected into a body \( \Omega \in R^2 \) through the electrodes \( e_l (l=1,2,\ldots,L) \) attached on the boundary \( \partial \Omega \) and the resistivity distribution \( \rho(x,y) \) is known for \( \Omega \) the corresponding electrical potential \( u(x,y) \) on \( \Omega \) can be determined uniquely from a partial differential equation, which can be derived from the Maxwell equations:

\[
\nabla \cdot \left( \frac{1}{\rho} \nabla u \right) = 0, x \in \Omega
\]

With the following boundary conditions based on the complete electrode model:

\[
\int _{e_l } \frac{1}{\rho} \frac{\partial u}{\partial \nu} \, ds = I_l, x \in e_l, l = 1,2,3,\ldots,L
\]

\[
\frac{1}{\rho} \frac{\partial u}{\partial \nu} = 0, x \in \partial \Omega \setminus \bigcup _{l=0} ^L e_l
\]

\[
u + z_l \frac{1}{\rho} \frac{\partial u}{\partial \nu} = U_l, x \in e_l, l = 1,2,\ldots,L
\]

Where \( z_l \) is the effective contact impedance between the \( l \)th electrode and electrolyte, \( u_l \) is the potential on the potential on the \( l \)th electrode, \( e_l \) is the \( l \)th electrode, \( n \) is the outward unit normal and \( L \) is the number of electrodes. In addition, the following two constraints for the injected currents and measured voltages ensure the existence and uniqueness of the solution:

\[
\sum _{l=0} ^L I_l = 0 \quad \text{and} \quad \sum _{l=0} ^L U_l = 0
\]

The computation of the potential \( u(x,y) \) on \( \Omega \) and the voltages \( u_l \) on the electrodes for the given resistivity distribution \( \rho(x,y) \) and boundary conditions is called the forward problem. In general, the forward problem cannot be solved analytically, so we have to resort to a numerical method. In the approach of forward solution is needed only for the computation of the Jacobian. The Jacobian is denoted \( U'(\rho_0) = J \) unless otherwise stated.
3. Simulation model condition and current pattern

The finite element mesh used in the calculations. Fig.1 shows calculation model condition. In the case of an annular flow are marked the pixel from around for two phase flow simulation. It has three cases by different marked number, the case is r=1, 3, 5. In the case of a stratify flow are marked the pixel from the bottom. It has three cases by different marked number, the case is h=3,8,12.

<table>
<thead>
<tr>
<th>Annular flow</th>
<th>pixel</th>
<th>r=1</th>
<th>r=3</th>
<th>r=5</th>
<th>Stratify flow</th>
<th>pixel</th>
<th>h=3</th>
<th>h=8</th>
<th>h=12</th>
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</tr>
</tbody>
</table>

Fig.1 Calculation model condition

Almost all EIT systems are designed such that they inject current and measure voltages instead of apply voltages and measure currents. The current is injected into the body through electrodes. A single current source requires switches that choose the electrodes that are used for current pattern injection. With only one current source, only current patterns that use two electrodes for current injection can be used. Next, the current patterns introduced two types for simulation. Trigonometric method is that the current is injected through equation 6. The electrode pair has fifteen pairs.

\[
I_k^l = \begin{cases} 
\cos(k\zeta_1) & l = 1,\ldots,L, k = 1,\ldots,L/2 \\
\sin((k - L/2)\zeta_1) & l = 1,\ldots,L, k = L/2 + 1,\ldots,L - 1 
\end{cases}
\]  

(6)

Where \(\zeta = 2\pi l/L\), \(k\) is current pattern number. Adjacent method is that the current is injected through two adjacent electrodes and the voltage differences are measured from all other pairs of electrode. This is repeated for all electrodes. The electrode pair have fifteen pairs like this 1-2,2-3,3-4,…,15-16.

4. Results & Discussions

The annular flow and the stratify flow was simulated by using two type current pattern. Contact impedances under the electrodes were assumed to be known in the reconstructions. The first simulated distribution was an annular flow model. Fig.2 shows a distribution in which there were two separate flows which had resistivities different. The correlation is higher when the pixel number is larger. However, the stratify flow simulation has high correlation each case. Moreover, the current pattern was compared each other.

Trigonometric method was carried out high correlation from among four current patterns.

<table>
<thead>
<tr>
<th></th>
<th>Annular flow</th>
<th>Stratify flow</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>r=1</td>
<td>r=3</td>
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<tr>
<td>Trigonometric</td>
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<tr>
<td>correlation</td>
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<td>0.9468</td>
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<tr>
<td>Adjacent</td>
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<tr>
<td>correlation</td>
<td>0.8517</td>
<td>0.9470</td>
</tr>
</tbody>
</table>

Fig.2 the result of flow simulation

5. Conclusions

EIT is used to simulate the annular flow and the stratify flow of pipe line cross section. Two current patterns are used for the injected current. Trigonometric method was carried out high correlation and the stratify flow calculated clear that the accuracy of reconstructed image in the multiphase flow.

Reference