Effect of Field Division on Electrical Capacitance Tomography System

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Abstract. Sensor sensitivity field in electrical capacitance tomography by multiphase flow effects of medium distribution, the soft field characteristic which brings great difficulty for image reconstruction, in order to improve the quality of image reconstruction, it is necessary for the distribution of the sensitivity field analysis. This article used the ANSYS software to carry on the modeling to the electrical capacitance tomography system, to exert the load and the finite element solves, gained the full pipe, the blank pipe and the central class changes the simulation capacitance value data in the grid, and carries on the analysis to the simulated data, has provided one kind of more accurate prior data for the keen field computation and the image reconstruction.

Keywords: electrical capacitance tomography, ANSYS, numerical simulation, mesh dividing.

1. Introduction

Electrical capacitance tomography (ECT) is based on capacitive principle of process tomography. It is a non-radioactive, non-invasive, quick response, low cost, well safety performance and Visualization technology. That can be applied in multi-phase flow, and also been widely used in chemical, petroleum, medical and transportation industries [1-5]. Its measuring principle is when the form or component in a pipeline flow changes, cause the dielectric constant dielectric pipe space change, which makes the capacitance sensor is different between the plates were changed, then according to the simulation have been calculated using the corresponding sensitivity field, image reconstruction algorithm, reconstruct the distribution of fluid chromatography the image is the image of medium distribution.

In the research of electrical capacitance tomography system, sensitive field by the multiphase flow effects of medium distribution, that is, the soft field characteristic brings great difficulty for image reconstruction. The permittivity distribution is very important to the flow pattern. ETC can acquire the permittivity distribution of the multi-phase. The sensitivity distribution in ETC system may affect the analysis of the permittivity distribution of the multi-phase.

This paper used the ANSYS software for the forward problem of ECT system to carry on the numerical simulation, the simulation data and on different grid in the simulation process form obtained were analyzed and summarized.

2. Research Method

For the ECT system with N electrode plate, the independent electrode can be obtained on a total of n:

$$n = \frac{N(N-1)}{2} \tag{1}$$

Electrical capacitance tomography sensor with 8 electrode used in the study, between the 8 electrodes can obtain 28 independent capacitance. The electrode of i, j between the capacitor is given by C_{ij}:

$$C_{i,j} = \frac{Q}{V_i - V_j} = \frac{\varepsilon_0}{V_i}\int_{(x,y)\subset\Gamma_i} \varepsilon(x,y)\nabla\varphi(x,y)ds,\ i = 1,2,\cdots,7;\ j = i+1, i+2,\cdots,8 \tag{2}$$

Where, Q is the induction charge detection electrode, $\varepsilon(x,y)$ is the permittivity close to the detection electrode, $\varphi(x,y)$ is the potential distribution, ∇ is the gradient operator. V_i is the incentive potential, as the detection electrodes are grounded: $V_j = 0$.

In order to reduce the influence of various interference of capacitance value, the plate of the capacitor value is normalized. The capacitance normalized value is $C_{i,j}^N$, then the:

$$C_{i,j}^N = \frac{C_{i,j} - C_{i,j}^l}{C_{i,j}^h - C_{i,j}^l}, i = 1,2,\cdots,7; j = i+1, i+2,\cdots,8 \tag{3}$$

Where, $C_{i,j}^l$ is the capacitance value of i, j plate for all units in the pipeline for the low dielectric constant; $C_{i,j}^h$ is the capacitance value of i, j plate for all units in the pipeline for the high dielectric constant.

ECT sensitive field distribution for each electrode capacitance sensitivity on the distribution of description, image reconstruction with the sensitivity distribution as prior knowledge. Suppose the whole cross section of the pipeline is divided into m units, unit 1~m in the internal pipeline. The sensitivity of the essence is the change of capacitance caused by the dielectric constant of a unit change occurs. K define a unit relative to the i, the sensitivity of j plate on the values of $S_{i,j}(k)$ for:

$$S_{i,j}(k) = \mu(k) \cdot \frac{C_{i,j}(k) - C_{i,j}^l}{(\varepsilon_h - \varepsilon_l)\left|C_{i,j}^h - C_{i,j}^l\right|}, i = 1,2,\cdots,7; j = i+1, i+2,\cdots,8 \tag{4}$$

Where, $C_{i,j}(k)$ is the capacitance value between electrode pair i-j when the k element is filled with higher permittivity material in the lower permittivity background and $\mu(k)$ is an area correction factor, which is assigned to the ratio of the area of the largest element to the area of the k element [5].

Because 8 electrodes with 28 capacitors $C_{i,j}$, considering the symmetry of the distribution of the electrodes, only 4 independent sensitive field $S_{i,j}(k)$, the rest can be obtained by rotating.

Given the distribution of the dielectric constant and the corresponding boundary conditions (the potential of each plate and shield value), the capacitance value calculated above available method, analytical solution of the equations is usually very difficult to obtain, but to use the finite element method (Finite Element Method, referred to as FEM) for the numerical solution. Similarly, the sensitivity distribution determined mostly by two dimensional finite element method for solving.

3. Results and Analysis

In this paper, the parameters of capacitance sensor are set as follows: The inner-radius of pipe is 50mm, outer-radius of pipe is 70mm, the radius of the shielding is 80mm, the electrode angle is 40°, the plate length is 120mm, and Plate number is eight. The permittivity are 1,20,6. The field is divided as Figure 1. Set 15 volts on incentive electrode, all the other electrodes are grounded, and the voltage is 0 volts.

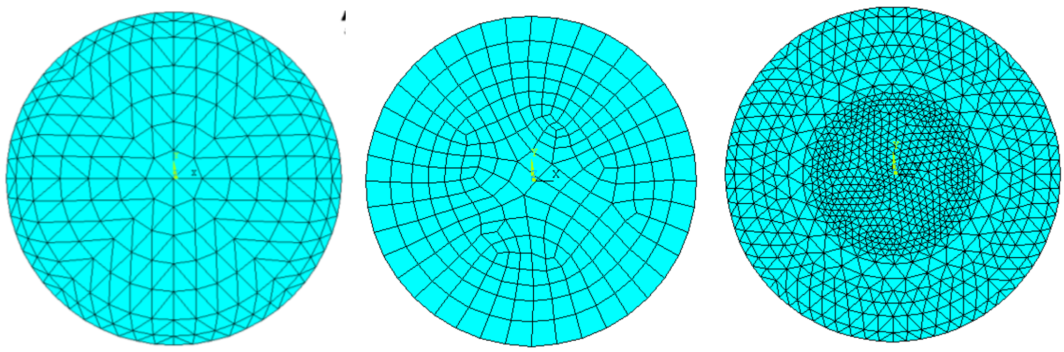

Figure 1. Finite Element Grid

3.1 Influence of element shape on simulation data.

This paper is divided into the number of grid 1-3 different cells, the simulation data are shown in table 1 and table 2.

Table 1. Electrode Capacitance of Empty Pipes

Electrode pair	1(pF)	2(pF)	3(pF)
C1-2	11.750	11.748	11.754
C1-3	0.94033	0.9403	0.94013
C1-4	0.50370	0.50370	0.50370
C1-5	0.4228	0.4228	0.42286
C1-6	0.50369	0.50370	0.50370
C1-7	0.94033	0.94028	0.94013
C1-8	11.750	11.748	11.749

Table 2. Electrode Capacitance of Full Pipes

Electrode pair	1(pF)	2(pF)	3(pF)
C1-2	18.629	18.627	18.633
C1-3	4.6844	4.6845	4.6841
C1-4	2.814	2.8140	2.8140
C1-5	2.4192	2.4193	2.4193
C1-6	2.8140	2.8140	2.8140
C1-7	4.6844	4.6844	4.6841
C1-8	18.629	18.626	18.628

From table 1 and table 2 data shows that the maximum error of the simulation of different grid capacitance value is 0.011 pF, smaller value. Thus, it can be think in ECT system in grid shape of capacitance value is almost negligible.

3.2 Influence of element number on simulation data.

This paper is divided into the number of grid 1 different cells, the simulation data are shown in table 3.

Table 3. Electrode Capacitance of Full Pipes for Different element number

Electrode pair	1014 unit(pF)	1462 unit(pF)	2572 unit(pF)
C1-2	22.358	21.220	19.405
C1-3	4.8816	4.8224	4.6965
C1-4	2.9193	2.8881	2.8209
C1-5	2.5071	2.4812	2.4251
C1-6	2.9193	2.8881	2.8209
C1-7	4.8816	4.8224	4.6965
C1-8	22.358	21.220	19.405

The data in Table 3 show that, the increase of the number of units, the biggest influence on adjacent plates, the relative plate minimum. The unit is fine, the calculation results more accurate calculation, the longer time. In addition to the adjacent plate of all the electrodes of simulation, to the adjacent plate can take experimental measurement method to reduce the error in order to improve the accuracy and reduce the computation time.

4. Conclusion

In this paper, the different grid of ECT system capacitance data simulation. The simulation results show that: grid shape, local refinement of ECT system simulation capacitance effects can be neglected; unit number of how many of the simulation capacitance value influence and had the greatest influence on the capacitance to adjacent, has little effect on the other plate of, the maximum value is less than 0.2 PF. So in the finite element method to obtain the prior data, using experimental method of adjacent electrodes on the other plate based on simulation method, the data a priori error reaches a minimum, for image reconstruction, sensor design and application of the actual system provides a new way of thinking.

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