

Monitoring Particle Flows by Displacement Current Sensing

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Abstract - A passive electrical topography system, which utilizes particle charge as a source, was developed. Two tomographic sensing methods, charge and displacement current, were applied. This system of eight electrode was settled three point in a cold riser and examined. Difference between obtained images by two sensing method correspond to internal solid circulation in riser.

Keywords: Displacement Current, Particle Charge, Process Tomography, Riser

1. INTRODUCTION

Electrical tomography is one of the most investigated field in process tomography. Capacitance, resistance and inductance sensing are positive methods and the main stream in electrical tomographic sensing. This paper deals with another alternative, electrical and passive sensing, for process tomography. In most case, particles in gas phase are electrically charged by friction to the wall and so on. It is an idea to utilize this particle charge as a source for sensing. Electrical field is generated due to these electrical charges, and also magnetic field when they move. When the change of these fields are detected, it is possible to monitor the behavior of particulate in gas media.

2. ELECTRICAL CHARGE AND DISPLACEMENT CURRENT

A moving charged particle can be regarded as a movement of charge. Therefore, a finite time flight of a charged particle is equivalent to a finite current in electromagnetism then is a source of magnetic field. When it is observed in static state, electrical charge generates electrical flux and induces surface charge on the sensor. A moving particle is a source of both electrical field and magnetic field. Relation between surface charge on the sensor and the displacement current from the sensor is shown (1) and a basic equation for the induction model of displacement current is described (2). In case of ordinary process monitoring, the last term, time derivative of

electrical flux, is valid and the other terms can be neglected.

$$q_{\text{sensor}} = \int I_{\text{sensor}} dt \quad (1)$$

$$I = \frac{1}{\mu_0} \oint_c \mathbf{B} \cdot d\mathbf{l} = \int_s \left(\mathbf{J}_f + \frac{\partial \mathbf{P}}{\partial t} + \nabla \times \mathbf{M} + \epsilon_0 \frac{\partial \mathbf{E}}{\partial t} \right) \cdot d\mathbf{a} \quad (2)$$

The amount of electrical flux flow into the sensor's surface can be correlated to the amount of charges in the sensing zone. Ratio of the flux captured by the sensor to the total flux from charge is a function of geometry of charge, sensor and surrounding conducting materials. Relation among them must be examined by experiment or numerical field calculation. Assuming that particles are charged to equilibrium, the amount of charges in the sensing zone can be proportional to the amount of particles in it. This is a basic concept of charge sensing.

On the other hand, displacement current does not only represent the amount of charges but also is effected by the velocity of the particle. Measured signals have to be transformed to power spectrum in order to obtain intensity. Information is mixture of charge and velocity.

Charge measurement is achieved with capacitance input and displacement current measurement with resistance input. Practically, the later one is easier to install for the reason of offset drift, time constant and so on. Charge can be calculated from current data by numerical summation with base line compensation. (see Figure 1)

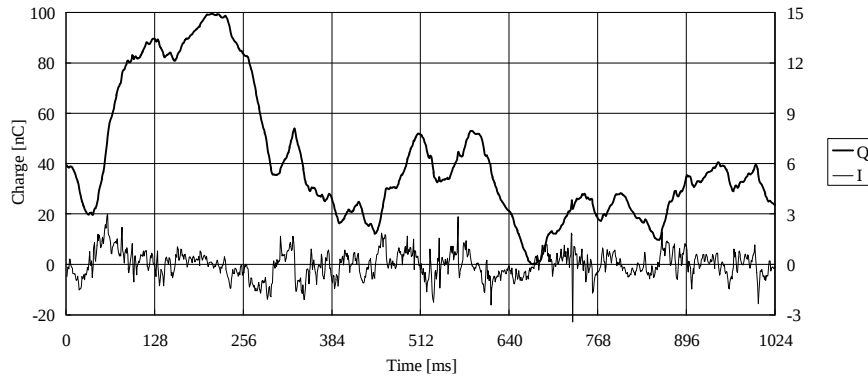


Figure 1 : Surface charge on sensor and displacement current from sensor

3. EXPERIMENTAL SETUP

Vertical gas-particle transport pipe, so called cold riser, was used as a target process. Pipe diameter was 4 inch(102mm) and transport length was 7m. Figure 2 shows the experimental rigs for the tomography system based on particle charge.

Alumina particles($D_{p50} = 80[\mu m]$, $r_s = 3030 [kg/m^3]$) were used as the test powder. The particles were fed to a vertical pipe at the bottom and were carried to the top by the air. Since the rig was earthen, the pipe itself had the shielding effect and is electrical boundary where potential equals to zero. Eight plate sensors of diameter of 25mm were mounted in the position, top, middle and bottom in riser which has diameter of 102mm.

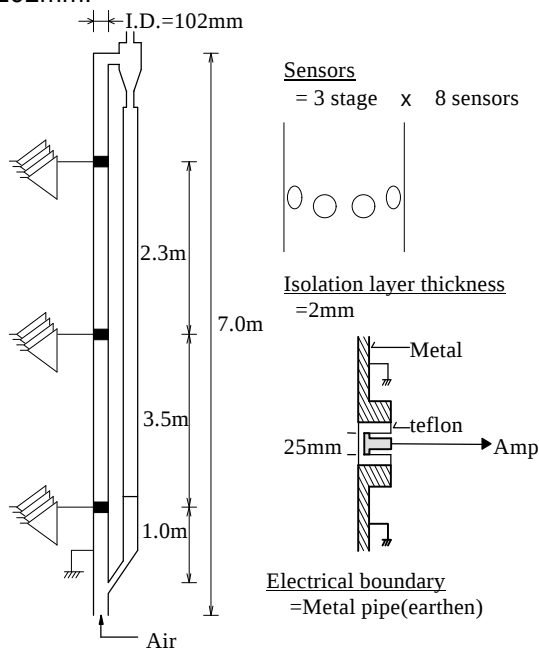


Figure-2 : Experimental setup and sensors

The sampling interval was 1ms and 1024 samples were collected in one measurement. Therefore, the range of detected frequencies lay between 1Hz and 1kHz which was enough to cover the characteristic frequency of the system.

4. RESULT AND COMPARISON BETWEEN IMAGES BY CHARGE SENSING AND DISPLACEMENT CURRENT SENSING

Tomographic image reconstruction with back projection method was tried on two kinds of data, displacement current and charge. The basic concept of image reconstruction is based on the 'Circle of Apollonius' which implies that two electrical charge create an equipotential circle. This concept implies that the signal intensities from any two sensors can specify the circle where the point charge exists.

Figure 3 shows the reconstructed images at the bottom of the riser in the condition of lower solid load, which means higher gas velocity and lower net solid circulation rate. Figure 4 shows that of higher solid load of lower gas velocity and higher net solid circulation rate. Since the same algorithm was used, images by displacement current show speckled profiles.

The difference between between Fig-3 and Fig-4 is the position of the cloud where particles should be exist. In higher solid load, the cloud is sometimes mapped in opposite side by displacement current and charge. On the other hand, in lower solid load, this tendency was not observed. Fig-5 shows image at the same time in three different position of the riser. Significant difference in position is observed at the bottom and small in middle and top.

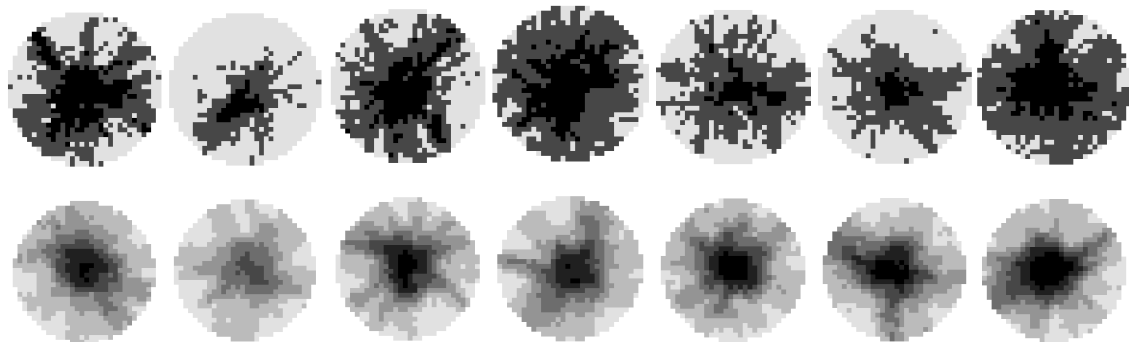


Figure 3 : Image at the bottom of riser in low solid load, $G_s = 40.0[\text{kg/m}^2\text{s}]$, Gas velocity = 8.5[m/s]
(upper = displacement current, lower = charge)

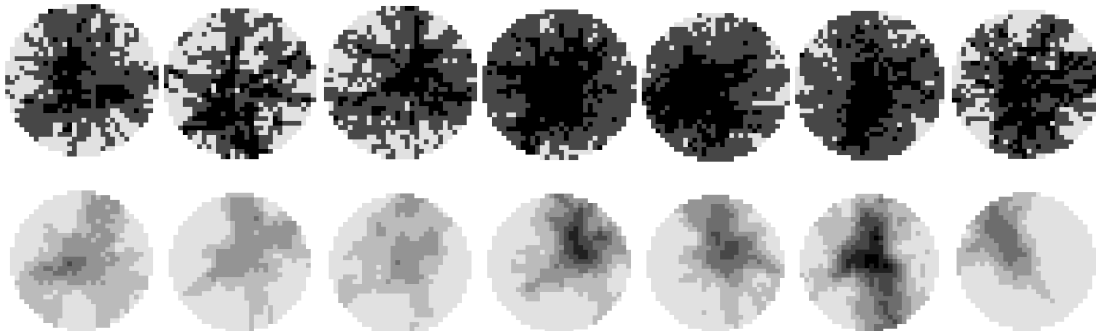


Figure 4 : Image at the bottom of riser in high solid load, $G_s = 59.1[\text{kg/m}^2\text{s}]$, Gas velocity = 7.3[m/s]
(upper = displacement current, lower = charge)

Transition from dilute pneumatic transportation region to circulation region is explained with the falling of cluster which is caused slip velocity between gas and particulate. The falling cluster has smaller velocity and lower voidage than the upflowing cloud of particles. And also the number of the falling cluster is higher in lower position of the riser. Since the displacement current sensing has sensitivity to velocity of charge and the charge sensing does not, the upflowing cloud is mainly detected in displacement current sensing and the falling cloud in charge sensing.⁴

	Top	Middle	Bottom
Displacement Current			
Charge			

Figure 5 : Image in high solid load
 $G_s = 59.1[\text{kg/m}^2\text{s}]$, Gas velocity = 7.3[m/s]

Though these results correspond to the transition of flow region in riser, the reconstructed image has problems. Image are blurs in central area, which means too high density in center and notches in image especially for displacement current tomography. This is considered due to the ghost generated by noise. More development,

improvement on reconstruction algorithm, separation of velocity information from displacement current and so on are necessary..

RERERENCES

- M.Horio, "Hydrodynamics", in "Circulating Fluidized Beds", Editors J. R. Grace, A. A. Avidin and T. M. Knowton, Blackie Academic & Professional, 21-85, 1997.
- C.S.Burrus, T.W.Parks, "DFT/FFT and convolution algorithms: Theory and implementation", Wiley, New York, 1985
- P.Lorrain, D.R.Corson, "Electromagnetism: Principles and applications", W.H.Freeman and Co., New York, 1978
- M.Machida, B.Scarlett, "Development of electrodynamic tomography system", "Frontiers in Process Tomography II", Delft, 167-171, 1997
- M.Machida, Dr. Ir. J.C.M. Marijnissen, B.Scarlett, "Mathematical model for charged particle measurement", J.Aerosol Sci., 27, S205, 1996