Applied ERT Technology in The Measurement of Concentration Distribution of Slurry in Horizontal Pipe

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ABSTRACT

The electrical resistance tomography (ERT) technology is briefly described and linear back projection (LBP) imaging algorithm is improved. A self-developed system based on ERT technology is tested and applied to the slurry transportation detection in horizontal pipeline. The distribution characteristics of slurry concentration within the pipe cross section under different flow velocities and concentrations are analyzed. Slurry transportation in pipeline has different flow regimes under different flow velocities and concentrations, and the limit deposition concentration is about 50%.

KEY WORDS: ERT; LBP algorithm; slurry transport; flow regimes; concentration distribution;

INTRODUCTION

In the hydraulic transport of solids, flow regimes are the physics depending on the flow velocity, particle diameter, concentration and pipe diameter. The flow regime identification is a key work to be completed in the research of slurry transport in pipeline. Durand (1953) proposed to divide the flow of non-settling slurry in horizontal pipes into four regimes based on average particle size. Considering the interrelation between particle sizes and deposition velocities, the original classification proposed by Durand (1953) has been modified to four flow regimes based on the actual flow of particles and their size (Abulnaga, 2002). Matosek (2004) gave the volume concentration distribution within the pipe cross section of different slurry flow regimes. It is a very intuitive way to identify flow regimes through volume concentration distribution within the pipe cross section. However, most instruments can only be used to measure the average concentration, and there are few reports on the measurement of slurry concentration distribution within the pipe cross section. Krupicka and Matousek (2015) used a radiometer to measure the slurry concentration distribution, but the radiometer is not the most ideal method due to its lack of safety and convenience.

In recent years, ERT technology has been developed rapidly due to its advantages of non-invasive, environmental-friendly and convenient. The technology was first applied in biomedical clinical by Baber and Brown (1984) and has been widely used in the field of multiphase flow detection. Franosolet (2005) analyzed the influence of non-Newtonian fluid viscosity on bubble size and distribution in bubble columns using electrical resistance tomography and dynamic gas disengagement technique. The study of oil-water two-phase flow pattern characteristics using ERT technology is reported by Huang (2015). The reports of the application of ERT technology in slurry concentration measurement are few. Different with the detection of oil-water two-phase flow and gas-water two-phase flow, the measurement of slurry concentration distribution focuses more on quantitative rather than qualitative. Imaging algorithm is one of the keys of ERT technology, and the Imaging algorithm of ERT technology can be divided into iterative algorithm and non-iterative algorithm. Commonly used iterative algorithms are Newton-Raphson algorithm (Fang, 2013, Xiao, 2012, Yorkey, 1987) and Landweber algorithm (Xiao, 2013, Yang, 1999). This type of algorithm can achieve high imaging accuracy but their reconstruction convergence can often not be reached if the data come with a certain level of electrode error and instrument noise (Wang, 2002). Commonly used non-iterative algorithms are LBP algorithm (Baber and Brown, 1984, Vogelius, 1990, Zhu, 2008) and sensitivity matrix algorithm (Wang, 2002, Yan, 2018). This type of algorithm has fast imaging speed and is suitable for online real-time measurement, but lacks measurement accuracy. Aiming at the disadvantage of LBP algorithm’s lower accuracy, we developed a double back projection algorithm based on the modification of LBP algorithm. The new algorithm was integrated into the concentration distribution measurement system developed by us based on ERT technology. The system was applied to the slurry transportation detection in horizontal pipe and the distribution characteristics of slurry concentration within the pipe section under different flow velocities and concentrations were analyzed.

ERT SYSTEM

The structure of a typical ERT system is shown in Fig. 1, which is mainly composed of the following parts: control unit, current excitation unit, sensitive electrode array, data acquisition and processing unit, and image reconstruction unit. The sensitive electrode array of the ERT system is arranged at equal intervals by rectangular electrodes. Apply excitation current to any pair of electrodes and measure the boundary voltage on the non-excited electrodes. The obtained measurement data is sent to the image reconstruction unit through the data acquisition and