Radioactive Particle Tracking Technique with Concentrated ^{68}Ga Source for Visualization of Water Flows in Digester with Vertical Impeller

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1. Introduction

It is very important to understand the dynamic behavior of mixing flow for operating digesters. Therefore, there have been incessant studies over the world to investigate hydrodynamic parameters of flows in digesters experimentally. In Korea, researchers at the Korea Atomic Energy Research Institute (KAERI) have been studying radioactive particle tracking (RPT) technique to tracks the trajectory of a single radioactive particle flowing along with flow current and then, hydrodynamics parameters are calculated based on the trajectory of particle [1-3]. In this study, the RPT technique was carried out for the digester mixed by a vertical impeller to visualize water flow.

2. Methods and Results

2.1 Lab-scale Digester with Vertical Impeller

The lab-scale digester, which is 50 cm in diameter and 40 cm in height as shown in Fig. 1, was built in 1/54 size of a real digester. The mixing in a digester is generally caused by either mechanical rotation impellers or gas blowers. But the digester taken into account in this study is designed with vertical impeller and it could reduce energy consumption by up to 90% [4]. To evaluate the performance of the digester, RPT technique was applied.

2.2 Radioactive Particle

In general, a ^{46}Sc, which is generated in a nuclear reactor by neutron activation, is used for RPT technique because its features (83.79 day of half-life, 0.889 and 1.121 MeV of gamma energy, and so on) are very suitable for that. However, in this study we tried to use ^{68}Ga (0.511 MeV of gamma) produced from ^{68}Ga generators as a radioactive particle not to depend on reactor operation cycles. The ^{68}Ga eluate comes out from generator in large volume as about 10 mL, so the eluate was concentrated to put into a 1 cm diameter polypropylene ball as much radioactivity as possible [5].

2.3 Experimental System Set-up

The RPT system was constructed with 15 NaI(Tl) detectors (2 inch in diameter and 2 inch height) as shown in Fig. 2. In detail, the detectors were installed on the 3 different height, and every 5 detectors was set on the same place by the shape of regular pentagon.

The detector data was accumulated by the 36 channel multi-channel analyzer (MCA) system developed by KAERI. Gamma-rays emitted from the produced radioactive particle is detected by the NaI(Tl) detectors, the detector data is collected by the 36 channel MCA system, and then the collected data is visualized by a Lab-view program [6].

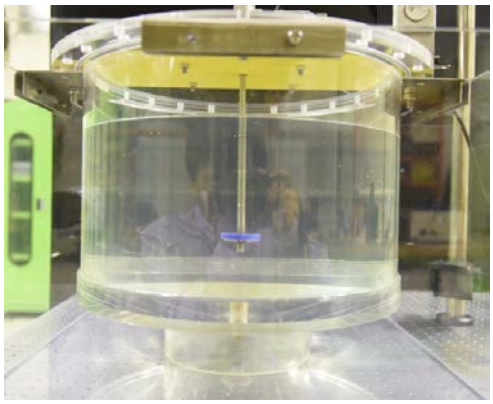

Fig. 1. Lab-scale digester with vertical impeller for radioactive particle tracking (RPT) technique.

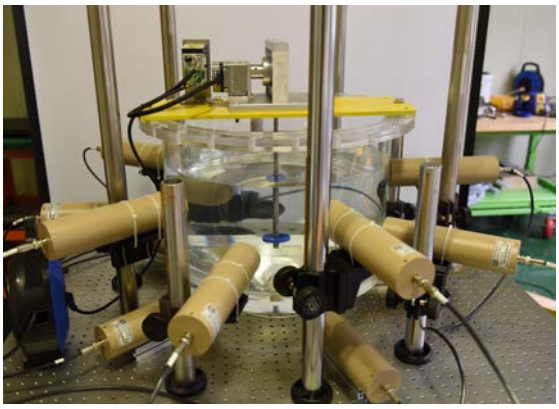

Fig. 2. The experimental set-up of radioactive particle tracking (RPT) technique for digester.

2.4 Particle Position Reconstruction

To reconstruct particle positions, the relation equation is necessary. In this study, MCNP6 simulation was carried out for the equation because it is hard to obtain the relation equation in water experimentally. First, we compared experiment data and simulation data in the air as a function of distance between detector and source. From this comparison, we founded out the calibration equation. And then, the relation equation in water was obtained by simulations and the calibration equation.

Particle trajectory was reconstructed by the linear-regression method [2]. The method calculates the source distance from each detectors by detection signal based on the relation equation.

3. Conclusions

In this study, the RPT technique was carried out to investigate water flows in digester mixed by vertical impeller. We used a ^{68}Ga generator source as a radioactive particle by concentrating eluate for RPT to be independent of reactors, and that is the first attempt in the world. The reconstructed particle trajectory will be used to calculate hydrodynamics parameters to understand the dynamic behavior of flows in digester.

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