Applied Radiation and Isotopes 101 (2015) 93–100

Contents lists available at ScienceDirect

Applied Radiation and Isotopes

journal homepage: www.elsevier.com/locate/apradiso

Investigation of hydrodynamic parameters in a draft tube reactor using radioisotope based techniques and conventional method

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HIGHLIGHTS

- Radioisotope based techniques were used to investigate flow dynamics in a draft tube reactor.
- The circulation time measured using RPT is longer than the circulation time measured by the SPECT.
- Radioactive particle tracking technique is expected to be helpful to investigate flow dynamics.

ARTICLE INFO

Article history:
Received 20 June 2014
Received in revised form
27 March 2015
Accepted 31 March 2015
Available online 3 April 2015

Keywords:
Gamma radiation
Radiotracer
Radioactive particle tracking
Three-dimension velocity vector
CFD model validation
Hydrodynamics of industrial process

ABSTRACT

In this study, various techniques were attempted to investigate flow dynamics in the enclosed reactor and the results from the techniques were compared. Radioactive particle tracking (RPT) and industrial single photon emission computed tomography (SPECT) were carried out and the circulation times from them showed a deviation of 17.5%. The circulation time of the RPT was longer than that of SPECT, and it is speculated that the physical dimension of the/ fabricated radioactive particle creates the discrepancy. Particle image velocimetry (PIV) measurements and computational fluid dynamic (CFD) simulations were conducted. The velocity patterns from them were similar to each other in the entire reactor region except near the propeller installed at the bottom of the reactor.

1. Introduction

Gamma radiation with high penetration energy has been widely used in various industries since it gives information about material movements through process walls during its operation. The typical technologies are radiotracer, densitometry, and industrial process tomography such as gamma CT and industrial SPECT. These technologies have played valuable roles in diverse applications for multiphase flow dynamics study and industrial process diagnosis.

Residence time distribution measurements using a radiotracer give global information about the characteristics of dispersion and convection of flow in the system under investigation. Industrial SPECT using a similar radiotracer, however, shows the change of two-dimensional radiotracer distribution as a function of time at a certain pre-determined cross-section plane of a system. Despite the flow visualization from Industrial SPECT technique, no information about vector flow over all space of a system can be obtained owing to the enormous number of radiotracer particles that cannot be distinguished from each other. As a result, critical flow properties for process design and operation such as back-mixing, circulation and stagnant zone localization cannot be achieved from those methods.

A radioactive particle tracking (RPT) uses a single fine particle flowing along with the flow stream without being dispersed into the flow. By tracking the trajectory of a radioactive particle in a system, it is possible to get those data that are expected from RTD or Industrial SPECT as well as the most fundamental information like a velocity vector from which the dynamic characteristics of a system can be deduced. Considerable research has been carried out to obtain liquid flow using the RPT technique by various researchers (Drahoš et al., 1992; Devanathan et al., 1990; Yang et al., 1992; Shaikh and Al-Dahhhan, 2007; Upadhyay et al., 2013; Pant, 2000).

There are also many methods to visualize flow velocity without radioisotope too. Particle image velocimetry (PIV) and computational

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http://dx.doi.org/10.1016/j.apradiso.2015.03.022
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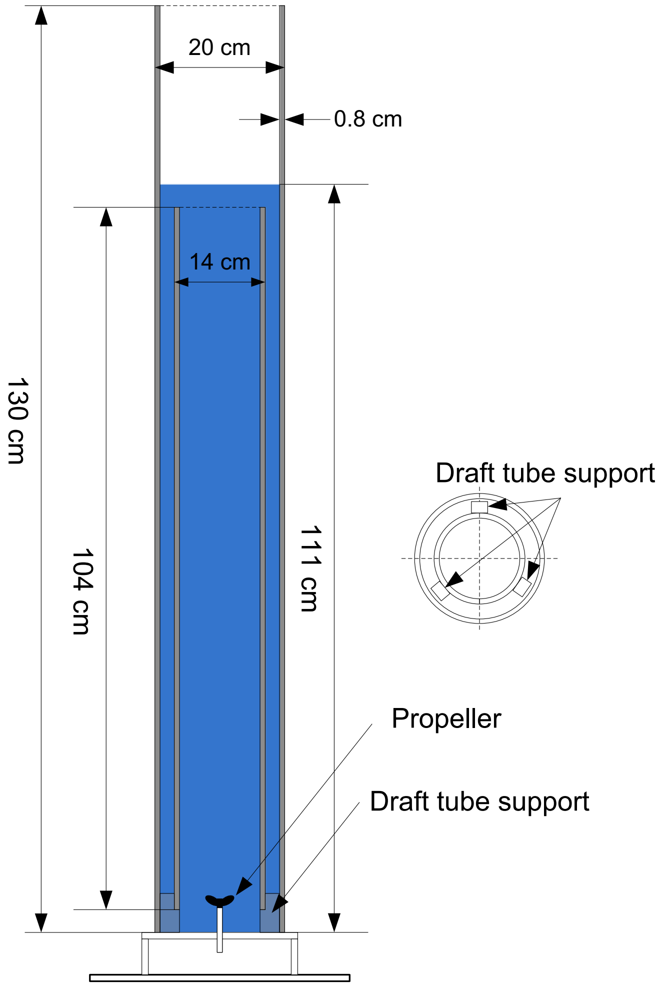

Fig. 1. A draft tube column reactor mounted with a propeller for water mixing.

fluid dynamic (CFD) analysis are two of them. The PIV estimates instantaneous velocity of fluid using a laser device and digital camera by sensing the movement of small tracer particles inserted in a system. But the PIV is only available for a single-phase flow in a transparent vessel. CFD analysis predicts fluid flow by calculating fluid mechanics equations. But it is necessary to verify the result with experimental data.

In this study, radioactive particle tracking (RPT), PIV, SPECT, and CFD were carried out with a propeller driven draft tube reactor where water is circulating around an inner cylindrical wall that separates water into two areas, upward and downward streams.

2. Internally circulating draft tube reactor

The enclosed reactor is primarily used as a photobioreactor in which axenic cultures are allowed by natural or artificial illumination (Cassano et al., 1995; Pulz and Scheibenbogen, 1998; Luo, 2005). So, it is important for a photobioreactor to make sure that materials to be treated are evenly exposed to light, because intensity of light illumination to the reactor surface decreases exponentially along the radial direction. The reactor was built with double transparent acrylic tubes, an inner draft tube with 14 cm diameter and 104 cm height and an outer column with 20 cm diameter and 130 cm height. A draft tube was mounted coaxially to the outer column by three tube supports installed on the column base. Clearance between the lower end of the draft tube and the bottom of the column was 2 cm. A two blade propeller of 3.4 cm diameter was used for the single phase circulation condition. The propeller is located 6 cm above the bottom of the column which is filled with water up to 111 cm elevation as shown in Fig. 1. During the experiment the rotation speed of the propeller was set to 1000 rpm.

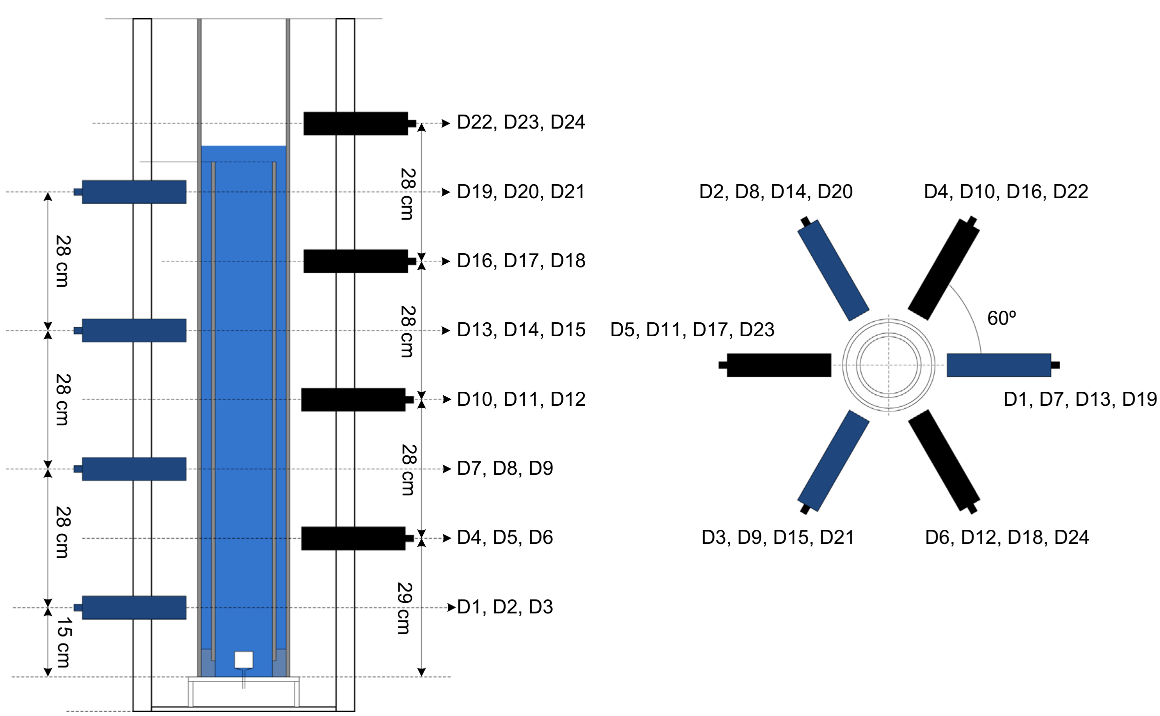

Fig. 2. Configuration of the radiation detectors mounted around the water column.