Reduced tomography to investigate inhomogeneous solid in multiphase column

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Abstract. Reduced tomography analyzed the data of cross section which no rotation and translation of the detectors and radioactive source. The main objective is investigating the industrial process in term of mechanical and process problems such as formation of catalyst/solid in multiphase packed bed column. A diameter of 0.2 m packed bed column was used in this study. The gas velocities were varied to get some movement of the particles. Multiple scanning was conducted using Industrial Process Computed Tomography instrumentation. However, only three detectors were used to collect and analyzed the data. The results were compared with other portable instruments with one source and three detectors manually. In addition, Monte Carlo modelling was conducted to get better results comparison. The results were successfully diagnostic any mechanical, and process problem such as maldistribution or channelling happen in the packed bed column.

1. Introduction

Industrial Process Computed Tomography usually using a lot of images to analyze the investigation process. The systems for computed tomography (CT) used many rotation and translation of the detector and radioactive source to get best image resolution. Many hydrodynamics studies have conducted to various types of column or pumps using non-invasive measurement techniques such as Gamma-ray CT to analyze gas hold distribution [1-3]. However, the CT systems take a lot of time, cost expensive and safety consideration. Industrial Computed tomography for process and mechanical diagnostic rarely used in refinery plants due to these shortcomings. A lot of factors such as column size, materials and height of the column obstruct the using of CT in the plants. Generally, the CT system is fixed and not yet has portable systems.

In industrial practice of gamma scanning for the packed bed column, multiple orientation of the scanning can determine any process and mechanical problems. It is also time consuming, many scanning orientation and radiation safety exposure. To overcome the shortcoming of CT and industrial practice of gamma scanning, the Reduced Gamma-ray Computed Tomography (RGCT) was introduced. RGCT can be defined as using the smallest number of scans and scanning orientation, less time of scanning and no movement of detector and source for translation and rotation. The ideas are to apply the concept of CT to any column in plants. This research aims to minimize the CT system operation and to overcome to industrial problems.

2. Experimental setup

Industrial Computed Process Tomography consists of a radioactive source of Cesium-137 (2.4 mCi) and 9 NaI scintillation detectors (figure 1). The inner diameter and height of the fluidized bed column
are 0.2 m and 1.14 m, respectively. A gas inlet of 0.02 m diameter in the bottom part of the column used to supply the compressed air. The column was packed with glass bead of 0.003 m diameter and bio ball of 0.0385m as to mimic as catalyst in usual plant operation condition for multiphase system.

![Industrial Computed Tomography System](image1.png)

![bio ball sample](image2.png)

**Figure 1.** (a) Industrial Computed Tomography System, (b) bio ball sample

The experiment was conducted to investigate distribution of the solid and gas holdup inside the multiphase column. Therefore, a range of gas velocities was applied to the fluidized bed. A multiple bio ball used to represent any corroded and degraded catalyst.
Figure 2. Model geometry of Industrial Computed Tomography for simulation study.

Multiple scans were conducted to represent cross section data. However, only detector 3, 5 and 7 data are analyzed to represent the concept of RGCT. Graph was plotted to determine any process and mechanical problems. A series of comparison was conducted with portable systems, Gamma Spider systems and Monte Carlo simulation system. Gas holdup calculation is a subtract between static radiation counts and dynamics systems which involved the change of gas flow rate.

For comparison with simulation, Photon and Heavy Ion Transport System (PHITS) [4], code which implemented the Monte Carlo method is used. The geometry for the simulation is setup as in figure 2. Simulation is calculating the gamma photon count at the three detectors from source pot through the column. In the simulation the material density inside the column is very from 0 to 8 g/cm$^3$ for simulating empty column at 0 and increasing density which represent different condition inside the column.

3. Results and discussions

Figure 3 demonstrates the results of the gas holdup versus gas flow rate. It was shown that at the beginning the gas holdup increases with the increase in gas flow rate. However, the gas holdup starts to decrease at the gas flow rate 180 SCFH for all detectors. This phenomenon can be described as the bio ball will always block the radiation signal as a result decrease the intensity counts.

![Image](image.png)

Figure 3. Gas Holdup vs Gas Flow Rate.

The gas holdup appeared some non-homogeneous solid distribution was observed during the operations. The findings can be compared with other instruments to get solid conclusions. Many factors involved of the findings such as the size of the solid, gas distributor design and columns sizes. Figure 4 shows the ideal solid distribution inside the column. The images were taken from Gamma Spider Instrumentation. Further analyses can be conducted from data collection.
Figure 4. (a) Empty column; (b) image of column with bio ball and glass bead.

Figure 5 shows the graph of photon counting at the three detectors namely, det-3, det-5, and det-7 versus density of material inside the column. The density is increased from 0 g/cm³ which represent empty column, and 1 g/cm³ to 8 g/cm³ to represent different condition inside the column. It can be seen the decreasing exponentially trend with increasing of density of the material inside the column. This is rightly followed the density dependent of photon attenuation. It can be seen both side detector has higher photon count compare to middle detector. This is due to path of the photon trajectory through the column in shorter compared to the middle detector which travel through the diameter of the column.

![Graph of photon count versus density](image)

**Figure 5.** Graph of photon count versus density of the material inside column.

4. Conclusion
In conclusion, the experiments indicate possibility to reduce the number of detector, time and scanning orientation to investigate flow distribution of the gas inside the packed bed reactor. The output will be in graph mode of gas holdup profile in multiphase systems. The results also compared with portable instrumentation, Gamma Spider instrumentation and Monte Carlo simulation. However, further experiments should be conducted in real plant or bigger diameter process column to get best results.

Acknowledgments
The authors would like to thank the Dr. Jaafar Abdullah (retired) for developed the Industrial Process Gamma Tomography from IAEA budget. Very special thanks go to Malaysian Nuclear Agency and PAT research group for their generous support and cooperation.
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