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Impact of measurement approach on the quality of gamma scanning density profile in a tray type lab-scale column

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HIGHLIGHTS

- The quality of density profile in gamma scanning technique has been studied.
- Quality of density profile depends on the measurement approach.
- A laboratory distillation column has been used as an illustrative example.
- MCNP4C Monte Carlo code has been used for simulations.

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ABSTRACT

This article presents a study for investigating impact of the measurement approach on the quality of gamma scanning density profile in tray type columns using experimental and computational evaluations. Experimental density profiles from the total and the photopeak count measurements, as two approaches in gamma ray column scanning technique, has been compared with the computational density profile from Monte Carlo simulation results. We used a laboratory distillation column of 51 cm diameter as an illustrative example for this investigation. ^{137}Cs was used as a gamma ray source with the activity of 296 MBq (8 mCi), with a NaI(Tl) detector. MCNP4C Monte Carlo code has been used for simulations. The quality of the density profile in the photopeak count approach is relatively within 155–204% better than that of the total count approach for experimental results. The same comparison for simulation results leads to a relative difference within 100–135% for the density profile.

1. Introduction

Gamma ray scanning has become a popular diagnostic tool for troubleshooting of distillation columns. The unique and most powerful aspect of using this technique for the troubleshooting of distillation columns is that it is online and completely nondestructive. This technique is also a fast, efficient and cost-effective tool to better understand dynamic processes taking place in industrial columns and to examine inner details of a distillation column (Pless and Asseln, 2002; Vasquez et al., 2005).

This technique, often refer to as "column scanning", can be used for any type of columns such as tray-type columns (one pass tray and double pass tray columns) and packed columns. The size of these columns in this technique varies in a large range. In order to scan these columns, no pre-preparation is usually required and the scanning can be performed by accessing the platform while it is operating (Abdullah, 2005; Walinjkar and Singh, 2011).

The main beneficiaries of this technique are Petrochemical and chemical process industries because distillation columns are one of their main components and the efficiency of the industrial plant relies on the ability of these columns to work as they were projected (Pless and Asseln, 2002; Zahran et al., 2011).

For troubleshooting of distillation columns, the mechanical drawing of the columns should be known. Understanding the inner details of a distillation column and their effects on density profiles obtained by gamma scanning technique help us to inspect structure of columns before its operation and also gives a good reference to better analyze the density profiles of the column when it is in operation. This scan as well as the gamma scans performed after startup or when the column is running normally can help us for better understanding and interpretation of density profiles when a malfunction occurs.

The quality of Density Profile and its capability in interpretation of structural specifications and diagnosis of the malfunctions is

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affected by utilization of total count or photopeak count in gamma ray column scanning.

Comparison of the photopeak and total count rates in gamma-ray transmission measurements has been discussed for Industrial gamma-ray tomographic scans (Kim et al., 2011).

In this work the difference between utilization of the photopeak count in comparison with total count in the quality of the obtained Density Profile has been evaluated experimentally and computationally for determination of the tray type columns structural specifications.

2. Principles of gamma ray column scanning technique

Column scanning is carried out using a small suitable sealed gamma-ray source, which is placed diagonally opposite to a radiation detector across the column. Both the source and the detector are moved simultaneously in small increments on opposite sides, along the exterior length of the column. Fig.1 shows a schematic diagram of principle of the column scanning technique by gamma rays.

The intensity of the transmitted gamma rays under ideal narrow-beam conditions is expressed by the following equation:

$$I = I_0 \exp(-\mu\rho t) \tag{1}$$

Where, I is the gamma-ray intensity transmitted through the material of thickness t, I_0 is the incident gamma-ray intensity, μ is the mass attenuation coefficient and ρ is the density of the material. The situation of a well-collimated source and detector are referred to as narrow-beam conditions. In this case, scattered photons are precluded from the measurement and thus the transmission measured reflects the bulk attenuating properties of the object alone.

For scanning a thick material, for example in column scanning, the assumption of ideal narrow beam is not valid because a significant number of photons may be scattered by the material into the detector. In this condition the intensity of gamma rays reaching the detector can be estimated by modification of Equation (1), through the use of a buildup factor B (is always greater than 1) according to Eq. 2 (Knoll, 2000).

$$I = B \times I_0 \exp(-\mu\rho t) \tag{2}$$

If we utilize total count to obtain the Density Profile, all the detector pulses from should be considered, while the photopeak counts, however, assumes only those source particles that have not any interaction before and deposit their full energy in the detector.

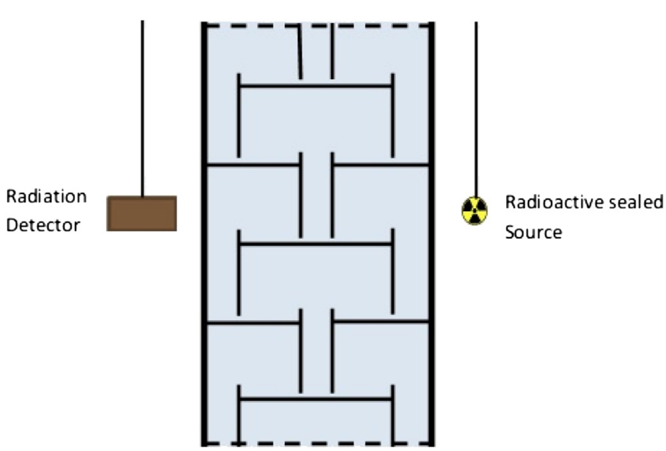

Fig. 1. A schematic diagram of principle of the column scanning technique by gamma rays.

Thus, in earlier case, the buildup factor in Equation (2) is almost1 and we can use Equation (1) as a good approximation. The difference between total count and the photopeak count has been shown in Fig. 2.

The photopeak count is not sensitive to some perturbing effects such as scattering from surrounding materials or spurious noise. Thus, utilization of photopeak count reduces the requirements for detector shielding in distillation columns scanning.

As we can see from Equation (1), the intensity of the gamma rays received at the detector decreases exponentially with increasing in the density and the thickness of the material between the source and the detector. In tray-type columns when the radiation passes through the trays or liquid, a great part of this radiation is absorbed and the radiation intensity reaching the detector is relatively small and when the radiation passes through steam, its intensity is relatively large.

3. Material and methods

As shown in Figs. 3 and 4, a laboratory one pass tray-type column of 51 cm diameter which has 6 steel made trays and downcomers has been used as an illustrative experimental example for investigation of the difference between utilization of photopeak count in comparison with total count in the quality of the obtained Density Profile. The thicknesses of the column and trays as well as their downcomers are 6 and 3 mm respectively. We used a Cs-137 gamma ray sealed source housed in cylindrical container having collimator role with the activity of 8 mCi (296 MBq). Also a 1 $\times$ 1 inch NaI (Tl) scintillation detector (Amcrys, 12s12/3) was used in this experiment.

Measurement system includes radiation detector the standard NIM units such as High Voltage power supply, Spectroscopy

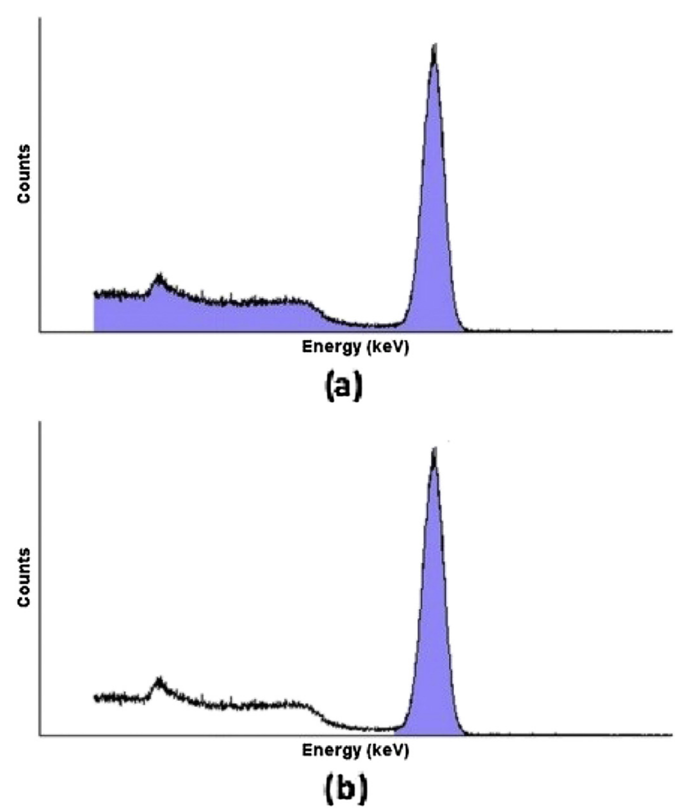

Fig. 2. Representation of (a) total count and (b) photopeak count of ^{137}Cs spectrum.