VELOCITY MAPPING IN A BINARY FLUIDIZED BED OF COAL AND GASIFIER ASH

Sangram Roy[1], Ashutosh Yadav[1], Manoj Ramteke[1], Harish J. Pant[2] and Shantanu Roy[1*]
[1]Department of Chemical Engineering, Indian Institute of Technology Delhi,
New Delhi 110016, India
[2]Isotopes Applications Division, Bhabha Atomic Research Centre,
Mumbai 400085, India

Abstract

We report Radioactive Particle Tracking (RPT) studies on a bench scale coal-ash mixture fluidized bed. This work combines two novel contributions. First, it presents a highly efficient novel algorithm combining traditional RPT tracer particle position rendering methods with genetic algorithms (Monte Carlo Real Coded Genetic Algorithm (MC-RGA). Second, we used RPT (implemented with this algorithm) to study the velocity fields in a fluidized bed of coal and bottom ash, mimicking real industrial gasifier mixtures

Keywords
Fluidized Bed, Radioactive Particle Tracking (RPT), Monte Carlo- Real Genetic Algorithm (MC-RGA)

Introduction

Fluidized bed reactors, with its widespread application in the energy sector, still remains technically challenging in operation and elusive to scale up. The key may possibly lie in developing robust modeling framework through CFD supplemented with suitable constitutive equations. In particular determination of hydrodynamic effects such as phase holdups and velocities may pave the path for superior closures. To this end, our goal here is to determine velocity of typical coal and ash particles in bench scale fluidized beds through Radioactive Particle Tracking (RPT). The wider objective of this effort pertains to developing a reliable database to benchmark velocity distributions for industrially relevant coal gasifiers and boilers.

However, the challenge in any particle tracking studies lies in accuracy in determination of tracer position in reasonable time. In order to address the limitation posed by the massive time required for reconstruction, a novel algorithm has been developed (Yadav et al. (2015)). This model combines a discrete model for emission, transmission and detection of gamma ray photons, using a Monte Carlo (MC) technique, with rapid position search using Non-Dominated Sorting in Genetic Algorithm (NSGA-II). The algorithm (which we are now calling Monte Carlo Real Coded Genetic Algorithm (MC-RGA), significantly brings down the time required for position rendering of the tracer particle in RPT implemented on any multiphase system. Further, it makes the method scalable to larger diameter vessels. Once a reliable position reconstruction was ensured, velocity measurements thorough RPT on bench scale fluidized bed of coal-ash mixture were performed.

Tracer Position Rendition by Monte Carlo Real Coded Genetic Algorithm (MC-RGA)

The efficacy of RPT technique relies on precise prediction of tracer particle location. Traditional position rendition algorithms based solely on MC technique relied on direct search method of photon counts registered by multiple γ detectors (Larachi et al., 1994). Corresponding to a certain set of photon count rate, tracer position was assigned based on a distance count map (i.e., a model of extrapolated mesh of counts with discrete location). However, such count generation (C_i) is based on a phenomenological relation involving complex optimization of the parameters - τ, ν and ε_i (Eq.1).

$$C_i = \frac{T\nu A\varepsilon_i\phi}{1+\tau\nu A\varepsilon_i\phi} \qquad (1)$$

* Corresponding author: Email- roys@chemical.iitd.ac.in, Ph- +91 11 2569 6021

Explanation on Eq. 1 can be found elsewhere (Larachi et al. 1994). In order to circumvent this issue, a novel MC-RGA algorithm was employed here (Yadav et al.). This combined MC-RGA approach hastens evaluation of optimized parameters of Eq. (1), yet retaining the accuracy of MC. As GAs work on an analogy of survival of fittest progeny, based on initial guesses, it intelligently exploits the random search for determining optimized values of parameters of Eq. (1).

Experimental

Fluidization experiments were performed on a laboratory scale fluidized bed of 13.8 cm ID employing dry air as fluidizing medium. The bed material was a mixture of coal and bottom ash. This entails to mimicking a possible state of fluidization by 'freezing' the properties of bed inventory. For present study, ^{46}Sc tracer embedded in a PVC bead was used as solid tracer. Table 1 below tabulates the detailed experimental conditions.

Table 1. Experimental Conditions

Parameter	Value
Test Section ID	13.8 cm
Bed Composition	70% Coal+30 % Bottom Ash
Superficial air velocity	4.06 m/s
Mean Particle Size	1.02±0.16 mm
Photon Sampling Rate	50Hz
Tracer Diameter	1.76±0.15 mm

Results

Figure 1 exhibits the instantaneous tracer locations in the test section in Cartesian representation for a period of 100s. It signified the fact that coal/ash particle movement in fluidized beds are highly dynamic and chaotic in nature. Such randomness enhances mixing and are particularly exploited for operations such as in gasifiers or boilers which demands faster transport of energy (heat). Further, mean velocities were evaluated by ensemble averaging instantaneous velocities. As the principal direction of convection is axial, the mean axial velocity tends to be higher in core and gradually decreases outwards (Figure 2a). In fact, negative velocities were also observed for locations very close to the wall. This could be possibly attributed to inability of the upward flowing air to carry the solids further due to their very low velocities near wall. The azimuthal averaged r.m.s axial velocity also exhibited a similar trend, due to conceivably a leaner core and relatively greater accumulation of coal-ash mixture in the vicinity of the wall. (Figure 2b).

Conclusions

This study reports velocity measurements of typical coal –ash particle employing RPT. Implementation of an *in-house* MC-RGA algorithm resulted in efficient tracer positon reconstruction. Instantaneous tracer locations showed that that it ensured an unbiased scanning of the entire test section. Also, the mean velocities revealed two distinctive zones – a high velocity region around core while relatively lower velocity towards wall.

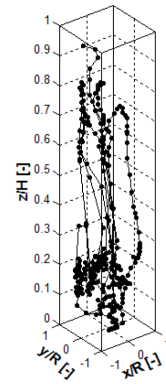
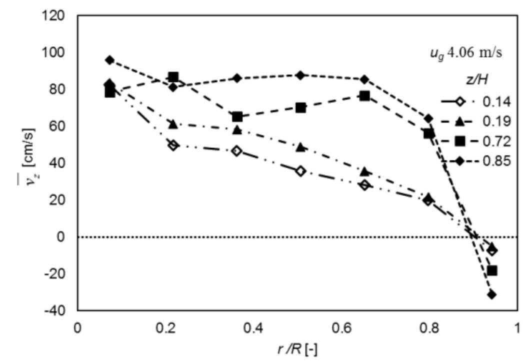
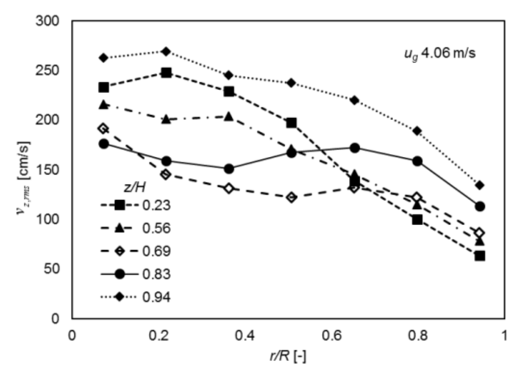


Figure 1. Instantaneous tracer position in the test section



(a)



(b)

Figure 2. Azimuthal averaged (a) axial and (b) rms velocity

References

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