
# Effect of Single/Multiple Nozzle Injection through Sidewall on Flow Field of Gas-Solids Fluidized Bed

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***Highlights***

- Hydrodynamics of fluidized bed with multiple nozzle injection was investigated
- Solid velocities, RMS velocities and Reynold shear stresses were estimated
- Granular temperature values were found relatively higher incase of nozzle injection
- Asymmetric velocity and granular temperature profiles were observed for single nozzle

## 1. Introduction

. Gas-solids fluidized beds are widely used for efficient contacting of gas-solids to achieve higher heat and mass transfer coefficients. However, in many applications, the secondary reactant/precursor needs to be added in the gas-solid fluidized bed for precise control of the rate of reaction and/or improve the selectivity of desired product. The secondary reactant is fed through single/multiple nozzle(s) placed at single/multiple axis on sidewalls [1]. The injection of secondary feed through the side nozzle(s) changes the hydrodynamics of the fluidized bed. The flow physics becomes more complex once multiple nozzle injections are used for high throughput systems. Though widely used in the industry, the hydrodynamics of such bed is not well studies due to complex interaction involved at a high nozzle injection velocity (~40-100 m/s).This high injection velocity creates severe instability inside the system. Further dense nature of gas-solids bed makes the investigation more difficult and does not allow optical based technique to investigate the system. In current work, radioactive particle tracking (RPT) technique is used to investigate the flow dynamics of gas-solids fluidized bed in the presence of single and multiple nozzle(s) injection. Solid mean, instantaneous and fluctuation velocity field are mapped and turbulent quantities like RMS velocities, Reynolds shear stress and granular temperature are also calculated for all the flow nozzle assembly. Finally, the effect of nozzle injection velocity for various nozzle assemblies is investigated to quantify the flow field in such reactor.

## 2. Methods

Experiments are performed in a cylindrical column (ID 0.21 m and height 2.3 m) made of mild steel. Glass beads of mean size 600$\mu m$ and density 2500$kg/m^3$ is used as solid phase and compressed air at atmospheric temperature is used as gas phase. Same compressed air is used as a secondary feed through side nozzle(s). Total nine nozzles are placed at three different axial planes with three nozzles per plane and $120^{\circ}$ apart from each other. The packed bed height for each experiment is kept constant at 0.75m. Experiments are performed at constant air inlet velocity of $3U_{mf}$ which is introduced through the bottom of the column through a perforated distributor. Effect of nozzle assembly and nozzle injection flow rate (varied between 80 to 120 LPM) on hydrodynamics of fluidized bed is investigated by using RPT technique. Total 12 NaI (Tl) scintillation detectors, which are placed strategically around the bed, are used in RPT experiments. Sc-46 doped in the glass beads of same size and density as of the solids present in the bed, is used as a traceras described by Upadhyay et al [2].

## 3. Results and discussion

Figure 1 shows the probability distribution function (PDF) of the instantaneous axial solid velocity for single nozzle injection operated at 80 LPM. The PDF is shown at three different radial locations, near the injection wall (r/R=-0.94), center of the column (r/R=0) and at the opposite wall (r/R=0.94), at the injection height. The results show that near the injection wall probability of particle moving upward is higher. Similarly at r/R=0, the upward solid movement was observed. The probability of negative velocity is higher near the opposite wall which indicates that solids are moving in upward direction near the nozzle injection wall and coming down through other wall which is different from the normal fluidized bed.

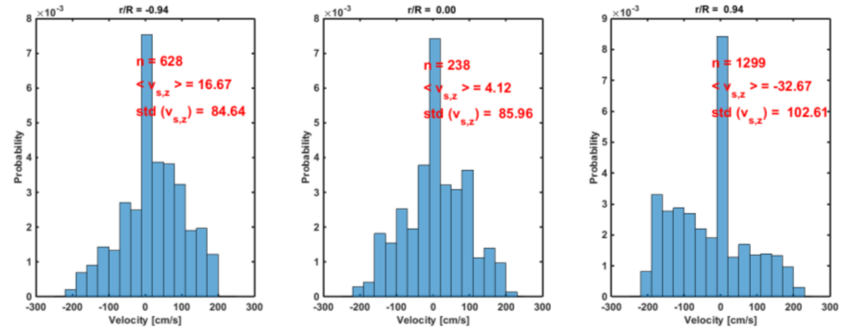


**Figure 1** *PDF of instantaneous axial velocity for single nozzle injection (flow rate 80 LPM) at injection plane for different radial locations*

Figure 2a and 2b show the radial variation of mean axial velocity and granular temperature respectively at three different axial locations along the YY' axis for single nozzle injection operated at 80 LPM. It is found that in time average sense particles are moving upward near the nozzle injection wall and coming down near the opposite wall at all the three axial planes. Figure 2b shows that granular temperature increases from r/R= -1 to r/R=1 at nozzle injection plane and above the nozzle injection plane while it decreases towards the opposite wall below the nozzle injection plane. This is mainly due to higher concentration of solids near the opposite wall at nozzle plane and above the nozzle plane. Similar results for all other conditions (with single/multiple nozzle injection) were also found.

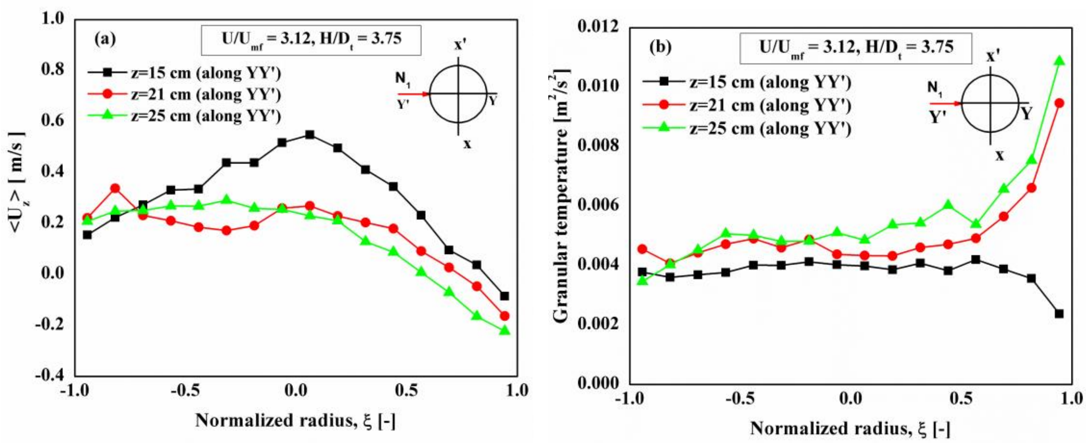


**Figure 2** *Radial profile of (a) time averaged mean axial velocity, (b) granular at three different heights with single nozzle injection along the injection plane*

## 4. Conclusions

Results obtained from the current work clearly show that the behavior of nozzle assisted fluidized bed is significantly different from the normal fluidized bed. Severe disturbance is recorded at nozzle injection plane which carried till top of the column for higher nozzle injection velocity. Further, for multiple nozzles injection, which is placed at same plane, the asymmetric behavior of the bed is minimized. However, nozzle placed at different planes on same side further create the asymmetric behavior which leads to higher by passing of injected material.

## References


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***Keywords***

Radioactive particle tracking; fluidization; solid velocity; nozzle injection; granular temperature