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Comparative study of gas–solids flow patterns inside novel multi-regime riser and conventional riser

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HIGHLIGHTS

- ▶ Systematic investigation of the flow patterns in a novel multi-regime riser.
- ▶ Detailed description of the local flow structure in the diameter-enlarged section.
- ▶ Comprehensive analysis of the transient solids concentration signals.
- ▶ Comparison of key flow features between the novel riser and the conventional riser.

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ABSTRACT

A novel CFB riser integrated with an enlarged bottom section was presented in this paper, with the aim to increase overall solids concentration, improve local flow structure and intensify gas–solids contact in the bottom region. Detailed measurements of the flow patterns indicated a multi-regime flow was achieved in this novel riser with a dense-phase bottom region and a dilute upper region. Compared with non-uniform radial profiles of solids concentration and particle velocity presented at the high-density bottom region of a conventional riser, high cross-sectional averaged solids concentration with limited radial gradient was observed in the diameter-enlarged section of this novel riser. Local flow structures in the bottom regions of both risers were also depicted. Better gas–solids contact over the conventional riser was confirmed by the analysis of transient signals and probability distribution of solids concentration. Finally, key flow features of the both risers were summarized.

1. Introduction

Circulating fluidized beds (CFBs) usually exhibit high gas–solids throughput with the advantages of continuous operation and independent control of gas–solids circulation rate, have been widely applied in many commercial processes, such as fluidized catalytic cracking, F–T synthesis, alumina roasting, coke combustion and gasification [1]. With the advancement of modern industry, the risers that generally serve as reactors for these processes have also undergone constant modifications to meet higher technological standard.

Based on comprehensive researches conducted on various CFBs, extremely non-uniform gas–solids suspension flow characterized by core-annulus flow pattern and solids back-mixing near the wall is often observed in the conventional risers [2–4]. Such non-uniform flow structure coupled with low solids concentration results in segregation of gas–solids phases and reduced gas–solids contact efficiency. Solids back-mixing is greatly reduced under high-flux [5] and high-density conditions [6,7]. The concept of high-density circulating fluidized bed (HDCFB) riser was first proposed by Bi and Zhu [8] and realized in a dual-loop CFB system. Grace et al. [9] defined HDCFB risers as operations under $G_s > 200$ kg/m^2 s and $\overline{\varepsilon_s} > 0.1$ through the entire riser, and "dense-suspension upflow" (DSU) regime was further proposed to represent the hydrodynamics in these high-density risers. However, obvious radial gradient of solids concentration with local ε_s increasing from less than 0.06 in the central region to about 0.44 near the wall still exists in the aforementioned studies conducted on HDCFB risers, which could still lead to gas bypassing and low gas–solids contacting quality.

Similarly, although the radial profiles of solids concentration and particle velocity in CFB downers are more uniform than those in the risers, and virtually no solids back-mixing near the wall, the overall solids concentration in the CFB downers is far less than the risers as a result of much higher particle velocity generated by

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