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Comparison of downer and riser flows in a circulating bed by means of optical fiber probe signals measurements

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Abstract

In this work, the riser (2.42 m high) and downer (0,85 m high) sections with an ID of 82 mm in both, were analyzed to study the temporal fluid dynamics properties of a circulating bed system in terms of electrical signals of particles concentration obtained by an optical fiber probe. Experiments were conducted using ambient air as the fluid phase and FCC (fluid catalytic cracking) particles as the solid phase. The measurements with the optical fiber probe were conducted in the inlet and outlet zones of both riser and downer. Signals were evaluated in the phase space (chaos analysis), by reconstructing the attractors and calculating the Kolmogorov entropy and the correlation dimension. Results show that the downer presents a less chaotic flow, with lower values of Kolmogorov entropy and correlation dimension, compared to the riser. In the entrance of the downer, the flow is less complex and more predictable in the center due to the effect of the solid feeder. The flow develops in direction of the exit zone and at that position there is no much difference in complexity between the central and wall. In the case of the riser, at the entrance effect is caused by a question of configuration, due to a presence of a curve, making the solid concentration increase toward the wall. In the exit zone, the flow suffers the effect of the abrupt exit.

Keywords: Riser; downer; optical fiber probe; temporal dynamics

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1. Introduction

Circulating fluidized beds (CFBs) are widely used in the petrochemical industry (e.g. Fluidized Catalytic Cracking - FCC units), metallurgical industry (e.g. calcinators) and in the energy sector (e.g. coal combustors). The advantages of CFBs include high efficiency and flexibility in catalyst or heat-carrier regeneration and control of the feeds [1]. In the case of FCC applications, the CFB can be divided into two basic parts, functioning as two separate reactors: the riser and downer. The riser reactor is characterized as a section of vertical transport in which there is a co-current contact between phases, flowing against the gravitational action. On the other hand, in tubular FCC downer reactors the co-current gas and solid phases move downwards.

CFBs in which particulate and gaseous phases have upward flows (riser) are widely used in chemical, metallurgical and petrochemical industries. Risers have many advantages over the conventional bubbling and turbulent fluidized bed, such as high efficiency of gas-solid contact and reduced axial dispersion [2]. However, riser reactors still has some shortcomings such as the downflow of solids in certain positions (typically near the wall) and the formation of clusters and non-uniformity in the radial and axial profiles, thereby reducing the efficiency of gas-solid contact and selectivity. These disadvantages can be reduced in a downer reactor [3], where the flow moves downward.

The local distribution of solids concentration, in particular its changes over time, are very important for any gas-solid operation. The time series of solid concentration contain information about the dynamics of the bed, and its transient behavior has influence on mass and heat transfers in CFBs. In this work, concentration signals are measured with an optical fiber probe in the downer and riser sections of a circulating bed. The time series gotten can be interpreted in the phase space domain (chaos analysis) and they are used to describe the fluid dynamics of the gas-solid flow.

2. Experimental

Experiments were performed in a laboratory-scale circulating bed (Figure 1). The riser section has 2.42 m high and the downer has 0.85 m high, both with and an ID of 82 mm. The gas phase is ambient air (25 ^{o}C) and the solid phase is FCC catalyst (d_p = 80μm, ρ_p = 902 kg/m^3). The gas distributor consists of four nozzles and, in contrast to many CFBs studied previously, e.g. [1,4], the feeding of air is parallel to the feeding of solids at the entrance of the downer section. After passing through the downer, the flow pass through a curve, then it is conduced to the riser. This configuration seems like a J-valve and allows a weak restriction on the riser bottom zone. The exit structure of the riser is an abrupt T-shaped exit (elbow with projected end) which can cause a strong restrictive exit effect.

Local measurements inside the riser were performed by means of a reflective-type optical probe (33 cm in length and 6 mm in ID), composed of 37 fibers to measure local electrical signals of concentrations.

Measurements of electrical signals relating to solids concentration were taken at two axial positions located in both downer (Z = 0.05 and 0.80 m) and riser (Z = 0.25 and 1.87 m) sections. Five radial measurements (r/R = 0, 0.25, 0.50, 0.75 and 0.875) were performed at each axial position. Operating conditions of solids mass flow and gas superficial velocity are presented in Table 1.