Use of chaotic invariants to identify regimes in circulating fluidized beds

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Abstract. This work addresses the fluidization regime identification from experimental time series of static pressure obtained along a cold fluidization column by means of chaotic invariants. The cold circulating fluidized bed FB plant is instrumented at three different points of the column for a spatiotemporal analysis. We propose a normalized chaos index based on the ratio of Kolmogorov entropy between different column positions, and a divergence parameter. The value of the divergence associated with the Hurst exponent (H) was able to identify all four fluidization regimes for all tested particles. The main contribution of this work is the proposal of a new spatiotemporal approach to identify fluidized bed regime based on chaotic invariants evaluated from static pressure time series.

Introduction

Circulating fluidized bed (CFB) gasifiers have great potential to convert large amounts of carbonaceous feedstocks (biomass, municipal and industrial solid waste) into fuel gas. In this conversion process, the inventory of solid mass is reduced, which hinders maintaining the desired fluidization regime. The regime identification is an essential task to control the process and ensure operational continuity. Important contributions to fluidization regimes characterization occurred when scientists showed the presence of chaos in time series of a gas-solid fluidized bed process [1]. Identifying the regime in a column fluidization is a nonlinear spatiotemporal problem. Some authors have attempted to identify local behaviour in CFB, but not the global fluidization regime of the column [2,3]. This work addresses the fluidization regime identification from experimental time series of static pressure obtained along a cold fluidization column by means of chaotic invariants.

Results and Discussion

The cold CFB plant is instrumented at the base (1), middle (3), and top (5) of the column for a spatiotemporal analysis. Three different particles – glass 355μm ID, sand 1.0mm ID, and sand 1.2mm ID – operating in four distinct regimes – expanded, bubbling, turbulent, and fast – are considered. We propose a normalized chaos index, $IK_{ij}\,(i, j = \{1, 3{,}5\})$, based on the ratio of Kolmogorov entropy between different column positions, and a divergence $d = IK_{53} - IK_{13}$. The value of the divergence associated with the Hurst exponent (H) was able to identify all four fluidization regimes for all tested particles. Figure 1(a) shows the evolution of IK_{13}, IK_{53} and IK_{15} for the four analyzed regimes, while Figure 1(b) depicts Hurst exponent for different column positions and regimes for the sand particle 1.0mm. As main result, we learned that the expanded regime is associated with $d \approx 0$, $H_3 \approx H_5$ and $H_1 > 0.7$; the bubbling regime is related to $d \approx 0$ and $H_1 < 0.7$; the turbulent regime occurs when $0 < d < max(d)$; while in fast regime d reaches its maximum value.

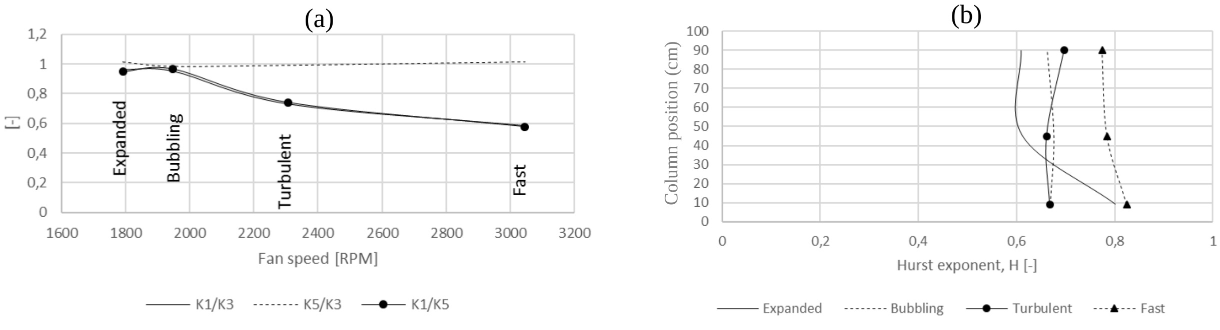

Figure 1: Results for sand 1.0mm: (a) Chaos indexes evolution in the different regimes; (b) Hurst exponent for different column positions and regimes.

References

[1] van den Bleek, C. M., Schouten, J. C., Deterministic chaos: a new tool in fluidized bed design and operation. *The Chemical Engineering Journal and the Biochemical Engineering Journal, 53*: 75-37, 1993.

[2] Letzel, H.M., Schouten, J.C., Krishna, R., van den Bleek, C.M., Characterization of regimes and regime transitions in bubble columns by chaos analysis of pressure signals. *Chemical Engineering Science, 52*: 4447-4459, 1997.

[3] Marzocchella, A., Zijerveld, R. C., Schouten, J. C., van den Bleek, C. M., Chaotic Behavior of Gas-Solids Flow in the Riser of a Laboratory-Scale Circulating Fluidized Bed. *AIChE Journal*, 43(6):1458 – 1468, 1997.