CHEMICAL ENGINEERING RESEARCH AND DESIGN 90 (2012) 336–345

Contents lists available at ScienceDirect

Chemical Engineering Research and Design

journal homepage: www.elsevier.com/locate/cherd

Highly swirling transient flows in spray dryers and consequent effect on modeling of particle deposition

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ABSTRACT

Cotton turf and hotwire measurements were used to experimentally assess the highly swirling flow characteristics in a spray dryer fitted with a rotary disc atomizer. The numerical simulation captured key features of the flow field. Analysis revealed that rapid rotation of an atomizing disc tends to centrifugally split the central inlet jet. The flow field exhibited significant long time-scale transient behaviour. However, this centrifugally split jet resulted in a balanced upward recirculation region in the chamber as expected by the jet-feedback mechanism. Detailed analysis using a 'transient air-steady particle' approach revealed that this approach is applicable for such highly swirling transient flows as well. However, caution should be exercised when interpreting the deposition results, particularly in regions of low particle velocities. This is anticipated be an important consideration in future attempts to simulate the predominantly transient flows in spray dryers.

Keywords: Spray dryer; Transient air flow; Rotating disc; Particle deposition; CFD

1. Introduction

The Computational Fluid Dynamics (CFD) technique has proven to be a valuable design and analysis tool to understand and manipulate the complex flow patterns and particle-air interactions within spray dryers (Woo et al., 2009a, 2010a; Guo et al., 2003; Straatsma et al., 1999). Such core phenomena must affect the drying process and transport of the dried particles. This technique, *hitherto*, has been utilized to evaluate chamber designs (Huang et al., 2003; Huang and Mujumdar, 2006), to evaluate industrial operations (Huang and Mujumdar, 2007) and to even look at the deposition problem prevalent in spray dryers (Langrish and Zbicinski, 1994). Therefore, better understanding of the complex air flow behaviour is essential in the intensification of the drying process.

Developments in this area have now shifted CFD simulation effort of the process to study the transient behaviour of the flow. Some seminal experimental work in understanding the long time scale transient behaviour in spray dryers can be found in the reports by Lebarbier et al. (2001) and Southwell and Langrish (2003). The transient behaviour was also investigated numerically to gain further understanding of the processing and flapping motion of the central jet in a spray dryer (Guo et al., 2003; Langrish et al., 2004). Woo et al. (2009a) found that such transient behaviour is also significantly affected by the size of the dryer by changing the dryer diameter in their numerical simulations. Such transient behaviour was also recently measured and observed in an industrial spray dryer fitted with a fluidised bed bottom at the bottom of the chamber (Gabites et al., 2010). Most of these simulations focused on non-swirling flows or mildly swirling flows, typically induced by inlet swirls. However, less attention has been placed on numerical studies of the highly swirling flows induced by the rapid rotation of the atomizer disc.

Huang et al. and Straatsma et al. have reported numerical studies of the spray dryers fitted with a rotating atomizer using the steady state approach (Straatsma et al., 1999; Huang et al., 2004). Similarly, in the simulation by Ullum (2006), it

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Received 19 November 2010; Received in revised form 23 June 2011; Accepted 29 June 2011
0263-8762/$ – see front matter
doi:10.1016/j.cherd.2011.06.019