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Chemical Engineering Journal

Chemical Engineering Journal

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

Gas recycling in fluidized bed to avoid defluidization for reactions accompanied by decrease in the number of moles

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HIGHLIGHTS

- ▶ Defluidization occurs when reactions are accompanied by a mole number decrease.
- ▶ Two operation modes of gas recycling were studied to establish stable operations.
- ▶ Defluidization zone is correlated by two parameters based on experimental data.
- ► A reactor model considers a decrease in the number of moles is used.
- ▶ The required recycle ratio is within the acceptable range for industrial operations.

ARTICLE INFO

Article history: Received 29 June 2012 Received in revised form 1 October 2012 Accepted 1 October 2012 Available online 14 November 2012

Keywords: Fluidization Fluidized bed Chemical reactors Defluidization Gas recycle

ABSTRACT

A gas recycling method for establishing stable operations of a fluidized catalyst bed is studied in order to perform reactions accompanied by a decrease in the number of moles. Two operation modes using gas recycling are evaluated to prevent defluidization and establish stable operation. For the first operation mode, because the influence of the decrease in the number of moles on the fluidization quality is reduced by adding a dilute gas to the feed, the reactor is operated with high conversion and a part of the outlet gas is recycled to the reactor inlet. The fluidization quality is also improved by decreasing the reaction rate. Therefore, for the second mode, the reactor is operated with low conversion, and the unreacted components in the outlet gas are separated from the product gas and recycled to the reactor inlet. It is possible to increase the overall conversion to a high level by gas recycling. Experimental data in previous studies and a fluidized-bed-reactor model that considers the decrease in the number of moles are used in order to determine the required recycle ratio and reaction rate constant for establishing a stable operation. Even when a reaction is accompanied by a 50% decrease in the number of moles, the required recycle ratio is below 9 for the recycle mode without separation and below 5.5 for the recycle mode with separation.

1. Introduction

When a reaction performed in a fluidized catalyst bed was accompanied by the decrease in the number of moles, the fluidization quality significantly decreased [1]. Observation of the bed behavior with a transparent glass column showed that severe defluidization had occurred [2]. The images from the precious study show that the defluidized part was lifted up through the column similar to a moving piston [3]. This part then collapsed from its bottom in the column and caused large pressure fluctuations. It reached the top of the column without breakup when the decrease in the mole number was large.

* Corresponding author. Tel./fax: +81 992858361. E-mail address: t.kai@cen.kagoshima-u.ac.jp (T. Kai). The gas velocity in the emulsion phase decreases as the reactions progress [4]. When the decrease in the gas velocity in the emulsion phase is not completely compensated for by the gas supply from the bubble phase, the gas drag force becomes too small to balance the gravitational and buoyancy forces acting on the particles. Consequently, the gas velocity in the emulsion phase decreases below than the minimum fluidization velocity, and the particles begin to agglomerate ultimately leading to defluidization.

The Fischer–Tropsch synthesis is one of the reactions accompanied by a large decrease in the number of moles. A Fischer–Tropsch process using a fluidized bed was carried out in the United States during the 1950s [5]. Defluidization occurred and good fluidization could not be established until the process was shut down owing to economic issues [6]. We suggest that the poor fluidization was partially caused by the decrease in the number of moles. Because many industrially useful reactions involve decrease in the number



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