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Variations of particle size and bed voidage distributions in expanded bed during transient operation processes

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Abstract

Changes in bed expansion are frequently encountered during an expanded bed adsorption, such as during the initial bed expansion, feed loading and washing processes. We have here studied the changes of local particle size distribution and bed voidage of an expanded bed in the initial bed expansion process as well as those during the changes in mobile phase viscosity, which imitated feed loading and column washing processes. Using a glass column modified with three side sampling ports and Streamline AC as the solid phase, experimental measurements on a series of operation moments during the transient processes were carried out by sampling the particles from within the column at different axial positions. In the initial bed expansion process, the gradual formation of an axial classification from a settled bed to a stable expanded bed was first displayed. By changing the mobile phase from water to 10% (w/w) glycerol solution or vice versa, the variations in both the particle size distribution and bed voidage corresponding to the increase or decrease of the bed height caused by the changes of the mobile phase viscosity were examined as well. The transient changes of the local particle size distribution and bed voidage first occurred in the bed bottom and then progressed from bottom to top along the axial direction. However, the changes of bed voidage at different axial positions were not unidirectional. That is, by changing the mobile phase to the high-viscosity glycerol solution, a constant increase of the bed voidage was observed in the bed bottom, while a distinct decrease of the bed voidage before its increase was involved at the middle and top positions. This is ascribed to the compression effect caused by the upward movement of the lower part particles.

Keywords: Expanded bed adsorption; Particle size distribution; Bed voidage; Transient phenomena

1. Introduction

Expanded bed adsorption (EBA) uses a purpose-designed column and adsorbent with a defined size and/or density distribution. In expanded bed operation, an upward flow of mobile phase through the adsorbent bed provides high bed voidage, which makes it possible for the particulate materials to pass through whilst the target bioproduct is adsorbed onto the solid phase. Thus, as a novel integrative technology for downstream bioprocessing, EBA has been widely employed to directly capture target bioproducts from cell containing broth, cell disruptate and other unclarified feedstocks [1–4]. This reduces both the process cost and operation time.

A successful operation of EBA depends on the formation of a stable fluidized bed even in the presence of turbid feedstock, which is characterized by a low back mixing, lack of stagnant zones and an ordered distribution of the adsorbent within the bed. Therefore, a variety of interactions between adsorbent and biomass in feedstock have been investigated to understand the EBA system [5–10]. Moreover, to achieve tighter control of the EBA process and to reach high process efficiency, it is desirable to understand the distribution of particle size and bed voidage within the bed during the operation since the liquid phase dispersion and adsorption behavior in the EBA column have a close relation to the axial particle size distribution [10–13]. Some authors have reported the particle size distributions and bed voidage along the axial height of the bed under stable bed expansion conditions [12,14–16]. However, to date, the information on particle size distribu-

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tions and bed voidage during transient operation processes is still unavailable.

Generally, the operation of an EBA can be divided into five stages, this is, (1) bed expansion and equilibration with an equilibration buffer, (2) application of feedstock, (3) washing, (4) product elution and (5) cleaning in place. The bed height increases in the bed expansion process. Additionally, the changes of expanded bed height also occur in the other stages due to the changes of mobile phase viscosity and density, if the flow rate is kept unchanged. The transient changes of bed height are especially distinct during the feedstock loading and washing stages, which are the key steps of an EBA process. The first phase of crude and viscous feedstock application leads to the increase of bed height, while bed washing with a low viscosity buffer after the feed loading results in the decrease of bed height. Such variation is particularly important when the feedstock loading volume is small in comparison to the bed volume since the change in bed height will exist during the whole loading process. Therefore, it is paramount to know how the distribution of adsorbent particles and bed voidage change during the transient processes. Such knowledge would help to control the EBA operation and to improve the process modeling and analysis.

In this work, we have studied the changes of local particle size distribution and bed voidage of an expanded bed in the initial bed expansion process as well as those during the changes in mobile phase viscosity, which imitated feed loading and bed washing processes. For this purpose, a glass column modified with side sampling ports was designed to study the transient phenomena. Using the commercial Streamline matrix as the solid phase, experimental measurements of local particle size distribution and bed voidage on different operation moments during the transient processes were carried out by sampling the matrix particles from within the column at different axial positions. As a result, comprehensive information on the transient phenomena in bed expansion, feed loading and washing processes was obtained.

2. Materials and methods

2.1. Solid matrix and chemicals

Streamline quartz base matrix (Streamline AC, Amersham Biosciences, Uppsala, Sweden) was used in all experiments. Its size distribution scanned with a Mastersizer 2000 unit (Malvern Instruments, Malvern, UK) was in the range of 80–500 μm, with a volume-weighted mean diameter of 210 μm. Expanded bed experiments were performed using deionized water and 10% (w/w) glycerol solution as the mobile phases. All other chemicals were of analytical grade from local sources.

2.2. Column design

A homemade glass column (0.7 m height, 25.15 mm I.D.) with a stainless steel mesh (opening size equivalent to 74 μm) as the liquid distributor was used for expanded bed experiments (Fig. 1). Glass beads (0.3–0.4 mm, 2.6 g mL^{-1}) were added in 1 cm height on the bed bottom to improve flow distribution at the column inlet. The glass column design followed that described previously [15], but modified with three sampling ports located at 1.2, 16.2 and 31.2 cm from the surface of the glass beads. Each port was sealed with silicone rubber, and the sealed section was well fit for the smooth inner surface of the column wall. Estimated by the

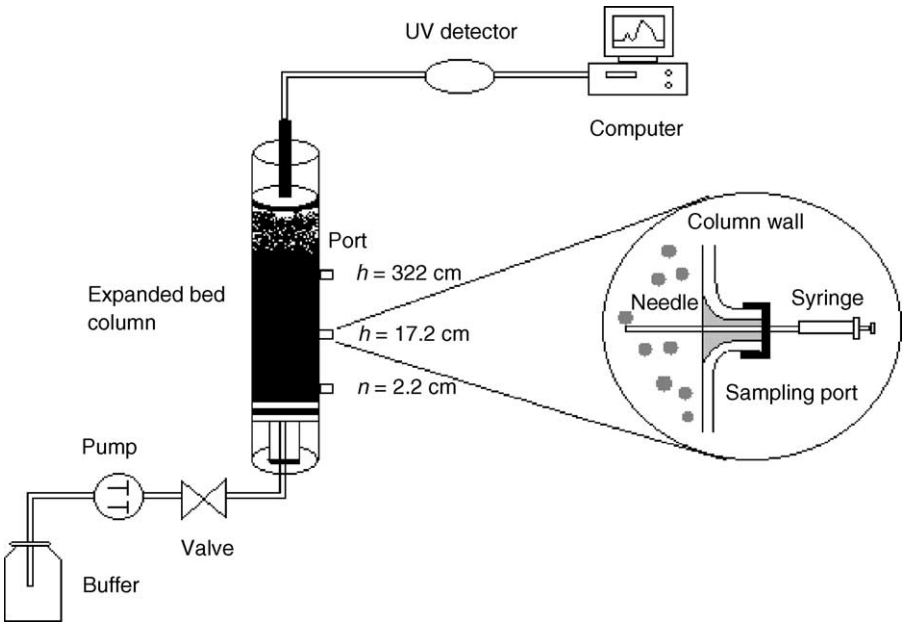

Fig. 1. A schematic diagram of the expanded bed system for sampling.