5 Magnetically Stabilized and Fluidized Beds in Science and Technology

A Review

Teresa Castelo-Grande, Paulo A. Augusto,
Angel M. Estevéz, Domingos Barbosa, Jesus Ma. Rodríguez,
Audelino Álvaro, and Cármen Torrente

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5.1 INTRODUCTION

Since the beginnings of science, separation of particles and substances has been an urged need for mankind. If, in the beginnings, the separation was obviously based on manual processing, nowadays the spectrum of high-tech techniques, devices, and processes used to achieve the separation has reached impressive levels.

Most areas where separation processes are applied demand different characteristics for the process itself. Namely, in chemical engineering processing industries, many times, efficiency is a factor that drives the selection of the separation process, sometimes at the expense of the degree of purity of the final product, while in chemical and pharmaceutical processing industries, the opposite happens several times. The processing of cells, biomedical substances, and/or high-valued biotechnological product substances has always been a major issue in bioengineering and biomedicine, and approximately 5% (in the case of wholesale products) up to 90% (in the case of pharmaceuticals) of the production costs result from downstream processing (Böhm and Pittermann 2000).

Magnetic methods are very attractive concerning the purification and isolation of substances, especially when allied with magnetic tagging and carrying technologies, because they represent a low-cost, effective process (Augusto et al. 2005). This is even more the case when day-after-day new methods to create and manipulate substances to effectively behave as magnetic carriers and tags are successfully demonstrated.

Magnetically stabilized and fluidized beds (MSFBs) exhibit a unique combination of packed-bed and fluidized-bed properties (Hausmann et al. 2000) and are one of the magnetic separation techniques used during the last decades to achieve the purification of substances. In this process, the magnetic particles (magnetic carriers or other type of tags) are placed within the influence of an external magnetic field that is capable to sustain them at flow velocities higher than in packed beds. These magnetic particles present some artificially manipulated affinity that enables them to collect/react with/adsorb/attach the target substance from the media that flows through them. They represent a very important factor for the efficiency of the overall process and so, must be carefully designed. Many of them are porous media, which is important for their performance.

Typical cases of application of magnetically stabilized beds (MSBs) in these areas of research are environmentally oriented, such as aerosol filtration, water treatment, waste removal, and metal ion removal, but also biomedically driven—for example, antibody removal and processing, fermentation, and cell and enzyme immobilization—and include typical chemical engineering processes, such as ammonia synthesis, mass transfer studies and applications, countercurrent contacting gas–solids magnetic valves, coal separation, and catalytic applications, (for example, purification of caprolactam, chlorophenol dehalogenation, and CH_4–CO_2 reforming).

Mass transfer and heat transfer studies, as well as hydrodynamic and more fundamental studies, are also important and will be referred to in this chapter.

In this chapter, we address all the topics detailed earlier, giving a clear insight of MSFBs in what concerns its fundamentals, mass and heat transfer characteristics, historical overview, present and future prospects, details of the particulate media used, and the main applications.

5.2 HISTORICAL OVERVIEW OF MSFBs

The first paper published regarding magnetically fluidized beds (MFBs) was of the authorship of Kirko and Filipov (Kirko and Filipov 1960). Filipov further developed this subject by investigating the behavior of a fluidized bed of iron particles under the influence of a magnetic field and the flow of a water stream and reported it in three subsequent papers (Filipov 1961a,b, 1962) that, complemented by the works of Nekrassov and Chekin (Nekrassov and Chekin 1956, 1961), initiated the investigation and development of the MFBs and MSBs. Figure 5.1 represents the device studied and developed by Filipov. Many publications on the subject have followed this breakthrough, and we may stand out as examples the following ones: Rosensweig (Rosensweig 1979) presented the first