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Particulate matter filtration of the flue gas from iron-ore sintering operations using a magnetically stabilized fluidized bed

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ABSTRACT

This study proposes a novel process for the separation of particulate matter (PM) from the flue gas emitted from iron-ore sintering operations using a magnetically stabilized fluidized bed (MSFB) with sintered ore as a filter medium. The deactivated sintered ore can still be used as a raw material for subsequent sintering operations. Sintered ore and sintered ash samples were characterized by x-ray diffraction, x-ray fluorescence, and laser diffraction analyses. The effects of collector size (150–300, 300–450, and 450–600 μm), applied magnetic flux density (48–160 Gs), bed height (5, 7.5, and 10 cm), and gas velocity ratio (1.40, 1.51, and 1.62) on PM filtration are investigated. The experimental results indicate that PM filtration efficiency increases with increasing magnetic field strength and bed height. However, a high gas velocity ratio has negative effects on PM removal performance, while collector size has little influence. A comparative study of the MSFB for magnetic sintered ash and non-magnetic coal-fired ash filtration demonstrates that sintered ash is more effectively captured due to magnetic retention. This indicates that this technology has good prospects for the purification of flue gas from iron-ore sintering operations.

1. Introduction

Sintering is a thermal treatment applied to ferrous materials, fuel, and rhyolite for preparing suitable raw materials in the production of iron using a blast furnace [1]. The sintering process is the main source of pollutant emissions in iron and steel plants, and includes pollutants such as particulate matter (PM), SO_2, NO_x, Hg, polychlorinated dibenzo-p-dioxins (PCDDs), and polychlorinated dibenzofurans (PCDFs) [2]; [3]; [4]; [5]; [6]. Increasingly stringent emission standards have progressively lowered the threshold limits of pollutant emissions worldwide. For example, China introduced the Emission Standard of Air Pollutants for Sintering Flue Gas (GB 28662–2012) in 2012, which required that PM concentrations of flue gas from sintering operations should be <50 mg/m^3 by 2015 [7]. This is a substantial challenge for some sintering plants.

Previous research [8]; [9]; [10]; [11]; [12]; [13]; [14]; [15]; [16] has investigated PM filtration from flue gas using fixed, fluidized or moving beds. Fixed-bed filtration generally exhibits high performance for small-diameter PM removal, and permits the passage of large gas flow [17]. However, the bed filter becomes gradually clogged with the collected PM, which progressively increases bed resistance. As a result, the filtration process must be halted while the bed is regenerated or replaced with fresh filter media. The inevitable downtime increases operational costs. One possible solution to this problem is to perform PM filtration using a fluidized bed or moving bed, which allows for the continual removal and introduction of the filter medium [18]. However, fluidized bed filtration suffers severely from the formation of gas bubbles that negatively affect the contact between PM and the filtration medium, resulting in relatively poor PM removal performance [19]; [20]; [21]; [22].

Based on above discussion, high-efficiency PM filtration can be obtained by restricting the formation of large gas bubbles in a fluidized-bed filter. In fact, gas bubbles can be eliminated entirely by maintaining the homogeneous gas fluidization of a fluidized bed of ferromagnetic particles via the application of an external magnetic field [23]; [24]. Such a system is denoted as a magnetically stabilized fluidized bed (MSFB). These systems offer the combined advantages of a conventional fixed bed (high filtration efficiency) and a fluidized bed (continuous operation). Studies have demonstrated the feasibility of MSFB systems for non-magnetic PM filtration (e.g., fly ash from coal-fired power plants and talc powder) [25]; [26]; [27]. The removal efficiency mainly depends on the effects of inertial impaction, interception, and Brownian diffusion [25]. However, few studies have focused on magnetic PM filtration using an MSFB, particularly for flue gas from iron-ore sintering processes, which is mainly composed of ferromagnetic iron oxide fly ash. In addition, MSFB systems have unique competitive advantages in comparison with conventional PM removal systems (i.e., electrostatic precipitators). For example, an MSFB system is suitable for high-temperature and high-pressure applications, and its PM removal

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