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Methane vs hydrogen as reductant gas for conversion of low-grade hematite to magnetite, a comparison study

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This study compares the performance of magnetic roasting using methane and hydrogen as reducing gases to convert non-magnetic low-grade hematite into magnetite, thereby improving iron grade and recovery through low-intensity magnetic separation. The effects of roasting temperature, duration, and reductant gas flow rate on the resulting magnetic iron concentrate were investigated and optimized. The results show that the hematite-to-magnetite transformation, which imparts strong magnetic properties to the roasted product, is primarily temperature-dependent. The optimum roasting temperatures for hydrogen and methane were 500 °C and 550 °C, respectively. Crack and pore formation during reduction increased the surface area of the roasted samples, facilitating subsequent grinding and separation of iron particles from gangue. Under optimal roasting and magnetic separation conditions, using methane at 550 °C, 0.1 L/min, 15 min, and 800 Oe yielded an iron concentrate grade of 56.81% with 80.39% recovery. Using hydrogen at 500 °C, 0.5 L/min, 15 min, and 800 Oe produced a concentrate grade of 60.07% with 81.35% recovery. This work provides the first direct comparison of methane and hydrogen for hematite reduction, offering new insights into the application of these gases as effective reductants in magnetic roasting.

1. Introduction

Non-magnetite iron-bearing minerals, such as hematite, limonite, and siderite, are the primary alternatives to magnetite in near future [1]. However, these low-grade deposits are not widely used in the iron and steel industry because of processing challenges, high operational costs, and their typically low-grade nature [2]. The selection of an appropriate beneficiation technique for iron ore separation is crucial and depends on the mineral composition and physical characteristics [3]. Magnetite, which is ferromagnetic, can be easily separated from gangue minerals using magnetic separation [4]. However the limits in these reservoirs makes the use of low-grade iron reserves mentioned earlier is unavoidable [5]. Hematite, which exhibits weak magnetic properties, presents difficulties in producing iron concentrate with a suitable grade and recovery from low-grade ore using magnetic separation alone, and in some cases, it may be impossible [6].

The primary method for processing hematite ore involves a complex combination of magnetic separation, flotation, and gravity separation [7]. However, this approach faces several challenges, including low iron recovery rates, high operational costs, and substantial water consumption, particularly for flotation systems [8]. These issues pose significant obstacles for large-scale iron production industries worldwide, particularly in regions with limited water resources, making iron extraction from these deposits technically and economically unfeasible [9–11]. Another major hurdle in hematite mining is the strong association between hematite and gangue minerals (predominantly silica), which makes it extremely difficult to achieve the necessary degree of separation to produce economically viable concentrates (containing over 60% total iron) [12]. Despite employing a combination of gravity, magnetic, and flotation separation methods, effective separation of hematite minerals from gangue remains a considerable challenge [13].

In the comparison of different processing methods for non-magnetite deposits, the reduction of hematite to magnetite along with magnetic separation is one of the most facile methods with the least associated economic and industrial consequences (such as not requiring water in the processing process and high capacity) [14]. In this method, iron oxides, hematite (Fe_2O_3), can be converted to magnetite (Fe_3O_4) by a reduction reaction, and the magnetized iron oxide is then easily separated from the tailings by

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