Process for the Recovery of Alumina and Iron from Bauxite Residue

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Abstract

Bauxite residue is a potential solid waste, generated during the extraction of alumina from bauxite ore by the Bayer process. For each tonne of alumina production, 1 to 1.5 tonnes of bauxite residue is generated depending on the grade of bauxite ore and the processing route. As the global alumina industry has been growing rapidly, the worldwide stockpiling of bauxite residue is rising and estimated to be more than 3.4 billion tonnes, with an annual growth rate of 0.12 billion tonnes. The bauxite residue, which is also known as red mud, causes serious disposal problem and harmful environmental impact due to its high alkalinity. Therefore, the need of a suitable technology for safe disposal and utilization of bauxite residue has attracted significant attention. At present, CSIR-Institute of Minerals and Materials Technology (CSIR-IMMT), Bhubaneswar is working on the processing of bauxite residue for the recovery of iron and alumina followed by the production of a concentrate, which can be processed subsequently as a valuable secondary resource of REEs (rare earth elements) and Ti. The present study is focused on the gaseous reduction of bauxite residue followed by melting operation to produce iron, a product for steel industry, and the aluminate slag suitable for the production of alumina. The aluminate slag is then processed through soda ash roasting-alkali leaching route to produce sodium aluminate solution for the recovery of alumina. Moreover, the concentration of mixed REEs in the residue is enriched by fourfold subsequent to separation of iron and alumina from bauxite residue.

Keywords: Bauxite residue, Iron, Alumina, Gaseous reduction, Soda ash roasting, REEs.

1. Introduction

The generation of bauxite residue during the production of alumina from bauxite ore is considered as one of the major concerns of alumina refineries throughout the world. In Bayer process after digestion of the bauxite ore in hot caustic solution, the bauxite residue is separated, washed, and disposed dry or in a pond. However, the disposal of bauxite residue has been challenging for the alumina plants due to high alkalinity (pH 11–13), fine particle size and large volume of residue [1–3].Depending on the bauxite source and the alumina extraction efficiency, the amount of bauxite residue generated per tonne of alumina production may vary between 1 to 1.5 tonnes [4].The disposal of bauxite residue may lead to extensive environmental pollution due to the presence of soluble compounds such as sodium carbonate, sodium hydroxide and sodium bicarbonate, which can get dissolved in rainwater and contaminate ground water [5].Furthermore, industries have been concerned about generation of a cleaner residue and making efforts to improve the current practice related to the use of red mud pond or dry landfills for environmental safety and land preservation [6]. However, these approaches are not suitable in terms of potential risk for the environment due to accidental dam failure or degradation of the stockpiling area. Therefore, for past several years, utilization of bauxite residue has received significant attention preferably in three aspects such as material applications related to cement and ceramics, environmental applications involving effluent treatment and disposal in landfills, and metallurgical utilization by the recovery of valuable metals present in the bauxite residue [7–12].However, cement preparation needs the alkali content of bauxite residue to be less than 1% to avoid alkali-aggregation reaction in the concrete, which may result in low strength and durability.

Bauxite residue is found to contain primarily oxides of Fe, Al, Ti, Si, Na, Ca and a few trace elements. Considering these metallic values present in the bauxite residue, many efforts have been made worldwide to recover them [10–13]. It has been reported that depending on the chemical and mineralogical characteristics of bauxite and the processing route for recovery of alumina, bauxite residue composition typically consists of 20–65% Fe_2O_3, 10–27% Al_2O_3, 5–25% TiO_2, 4–20% SiO_2, 2–8 % Na_2O, and <0.1% REEs [14–16]. Studies on the recovery of metal values from bauxite residue are substantial. Since Fe is the major constituent with maximum concentration, recovery of Fe from bauxite residue has been studied by many researchers. Different approaches involving magnetic separation, pyrometallurgical processing or combination of both have been developed targeting the extraction of Fe from bauxite residue [1,17]. The direct magnetic separation approach may not result in selective and effective separation of Fe from bauxite residue due to lack of magnetic iron-bearing mineralogical phases. Therefore, the pyrometallurgical route involving reductive roasting as well as reductive smelting may be preferred for an efficient recovery of Fe [18–20]. However, the type of reductant and operating conditions employed in the reductive roasting or smelting process play critical role in achieving higher extraction efficiency of Fe along with desirable grade or purity [1]. Literature reports suggest that high temperature hydrometallurgy and alkali roasting/sintering are primarily suitable for the dissolution of Al from bauxite residue [21,22]. On the other hand, for the extraction of Ti and REEs, acidic treatments involving hydrochloric acid, sulfuric acid leaching or combination of both acids may be employed [4,23–25].However, there is a scope for improving selectivity and efficiency for dissolution of REEs from bauxite residue [25]. As reported in the literature, the extraction of individual metal value such as Fe, Al, or Ti from bauxite residue has been studied extensively, but industrial viability of these processes are yet to be established.

Although recovering the valuable metals from bauxite residue is a beneficial way of its utilization from economical and sustainable viewpoint, the metal recovery technologies developed so far mostly emphasize on recovering a single metal component, and the trial to recover two or more metallic components is recently under active way. Therefore, keeping this in view, the present work is targeted to recover iron and alumina from bauxite residue. Following the recovery of iron and alumina, a concentrate enriched with REEs and titania is generated, and it can be processed further for the recovery of REEs and titania.

2. Materials and Methods

The composition of the bauxite residue sample collected from NALCO (National Aluminium CompanyLtd.), Damanjodi, India is shown in Table 1. Pellets in the size range of 2–3 mm were prepared out of the bauxite residue powder sample by a pelletizer. The bauxite residue pellets were then subjected to gaseous reduction roasting using a furnace with facilities for top charging of bauxite residue and gas inlet from the bottom. Subsequent to completion of reduction roasting, the reduced pellets were cooled using a nitrogen gas chamber placed at the bottom of the furnace

5. References

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