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Characterization of Red Mud treated under high temperature fluidization

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ABSTRACT

Red Mud (RM) is fluidized at different temperatures in a fluidized bed reactor (FBR). The phase composition and structural transition of RM fluidized at different temperatures are investigated. RM is treated in the FBR at different temperatures and above minimum fluidization velocity. The characteristic properties of RM treated in FBR at different temperatures are analyzed using XRD, TGA–DTA, PSA, FESEM, FT-IR and BET apparatus. It is observed that the different components of RM decompose on treatment of high temperature. The results thus obtained from RM treated at room and at higher temperatures are found to be much more promising where the temperature required for the decomposition of certain components is much less than the conventional heating methods. It is observed that gibbsite ($Al(OH)_3$) decomposes into Al_2O_3 & H_2O and calcite decomposes into CaO and CO_2 at higher temperatures. The particle size of treated RM is also analyzed where the particle size is found to increase initially and then decrease with the increase in temperature. The results obtained will thus provide an important base for the comprehensive utilization of RM for different applications.

1. Introduction

Red Mud (RM) is a reddish brown colored solid waste product produced in huge amounts from Aluminum Industries. The Bayer process is generally used in these industries for the digestion of bauxite ore in concentrated NaOH solution at appropriate temperature and pressure. During the digestion process aluminum reacts with NaOH to form soluble sodium aluminate leaving RM slurry as a waste [1]. It is reported that 0.8–1.5 tons of RM is generated per ton of alumina produced [2]. Globally 60–120 million tons of RM is produced annually and about 2 million tons of RM is produced in India itself [3]. The RM produced from these industries is generally stockpiled in open yard, which leads to serious problems in soil, air and water because it is highly caustic in nature [4]. The disposal of RM is now a major headache for the government for which researchers are currently working to develop suitable methods by which it can be utilized effectively. Thus the study of RM treatment and its utilization is very important and challenging.

Before working on RM for any use, it is essential to know its characteristics. The primary composition of RM is Al_2O_3 (17–20%), Fe_2O_3 (48–54%), SiO_2 (4–6%), TiO_2 (3–4%), Na_2O (3–5%), and CaO (1–2%) [5]. Various researchers are currently carrying out research work on RM treatment and utilization throughout the world. The researches include the recovery of important elements like Fe, Al, Na [6–8] and rare earth elements like Sc, Y, La, Ti, and V [8–12]. RM is now being used for cement production [13–16,32], brick production [17,18], glass production [19,20], aerated concrete blocks [21], filling material in mining [22,23], plastic [24], absorb heavy metallic ions like Cu^{2+}, Zn^{2+}, Ni^{2+}, and Cd^{2+} [25–27], removal of H_2S [28], removal of fluoride [29] and also for ceramic industry application [31].

Fluidized bed reactors are found to have huge applications in last few decades as compared to the fixed bed reactors and have become a versatile fluid–solid contacting device in chemical, bio-chemical, metallurgical and thermal power industries. The chief advantage lies in the fact that the solid particles get vigorously agitated in the bed by the fluidizing fluid passing through the bed thereby resulting in little or no temperature gradient even with highly endothermic and exothermic reactions [30].

For a better understanding of the physical and chemical properties of RM, the study of its behavior at higher temperature is very important. Various researches have already carried out researches to study the effect of temperature on the behavior of RM for knowing the physical and chemical properties where the RM samples were heated either inside an oven or inside a furnace or both [33,38], but the study of RM at higher temperatures inside a FBR is very much limited. Thus in this article focus is given to study the effect of temperature on characteristics of RM under fluidizing conditions. The research is supported by the characterization techniques such as XRD, TGA–DTA, particle size analyzer, FESEM and BET. This study provides an important base for the further studies on the behavior of RM inside a FBR.

2. Material and methods

2.1. Materials

The RM used in this study is collected from NALCO, Damanjodi, Odisha, India. The FBR used in this study is a cylindrical stainless steel

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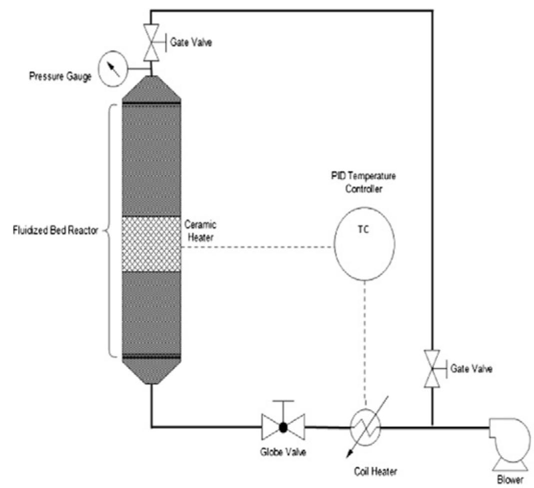
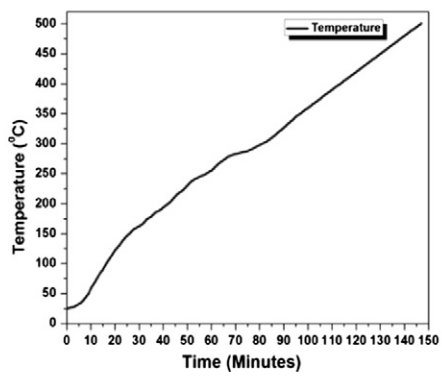


(a) Schematic view of the experimental setup

(b) Laboratory view of the experimental setup



(c) Heating curve of Red Mudinside the FBR

Fig. 1. (a) Schematic view of the experimental setup. (b) Laboratory view of the experimental setup. (c) Heating curve of Red Mud inside the FBR.

shell of 10 cm internal diameter and 90 cm height. The experimental setup is as shown in Fig. 1(a) and (b).

2.2. Material preparation

The RM is produced in slurry form. On drying this slurry, lumps of RM are produced. The collected RM lumps are initially ground inside a ball mill and are then sieved. The average particle size of RM is found to be 77 μm by sieve analysis. 500 g of the sieved RM sample obtained is then taken in the FBR up to a certain height. The power supply is made on. The air flow is made through the blower. A heater is provided outside the FBR to maintain the bed temperature. The bed material is then made to fluidize just above the minimum fluidization velocity. The temperature is controlled by a PID controller and a temperature probe is inserted within the reactor by which inside temperature is noted. Four different samples are collected batch wise at fluidized temperatures of 150 °C, 200 °C, 250 °C and 500 °C and characterized by different methods. The observations are then compared with those of the samples fluidized at room temperature.

2.3. Heating process

The reactor takes almost 26 min to attain a temperature of 150 °C, 42 min to reach 200 °C, 58 min to reach 250 °C and 147 min to reach 500 °C. This temperature profile is shown in Fig. 1(c). At the attainment of the required temperatures, the reactor is opened and the sample is collected using a sample collector.

Table 1
List of apparatus.

Analysis	Equipment	Range
XRD analysis	Philips X'Pert X-Ray diffractometer	2θ range of 10° to 70° (spanning range of 3°min^{-1})
TGA analysis	Shimadzu DTG	28 °C to 500 °C (N_2 atmosphere)
Differential scanning calorimetry	Shimadzu DTG	28 °C to 500 °C (N_2 atmosphere)
Particle size	Malvern Mastersizer (Hydro 2000MU)	0.02 μ to 2000 μ
FESEM	Nova NanoSEM 450	–
EDX	Nova NanoSEM 450	–
FT-IR spectra	Perkin Elmer FT-IR Spectrometer (Spectrum RX-I)	4000–400 cm^{-1}
Surface area	BET (Quantachrome Autosorb-1)	–