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Pelletization of magnetite ore with colemanite added organic binders

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ABSTRACT

A new generation binder consisting of an organic binder and a borate salt was tested as an alternative to bentonite in magnetite ore pelletization. Carboxyl methyl cellulose (CMC), Ciba DPEP06-0007 and corn starch, and calcined colemanite were used as organic binders and the borate salt, respectively. They were added to the pellet feed separately and in different combinations at several addition levels. It was found that the use of organic binders is sufficient in terms of wet pellet quality; however, they fail to render the required compressive strength to pre-heated and fired pellets. Therefore, organic binders and calcined colemanite were used together so that wet pellets, pre-heated and fired pellets would be of the required quality. The results showed that the use of an organic binder together with calcined colemanite indeed yielded pellets with equal or better wet and indurated pellet qualities compared to the pellets produced with bentonite binder alone.

1. Introduction

Bentonite is the conventional binder in iron ore pelletization and used at 0.5–1.5% addition levels in the pellet feed by weight of iron ore [1–3]. It controls the moisture of iron ore concentrate in the pellet feed and improves physical properties of the wet, dry, pre-heated and fired pellets. However, there are some drawbacks with the use of bentonite. The most remarkable is the contamination of the product with silica and alumina gangues which are main constituents of bentonite [4]. Since, bentonite is aluminum-silicate clay; it adds SiO_2 and Al_2O_3 to iron ore concentrate which is the product of an enrichment process for the removal of these impurities. In iron ore pelletization, addition of 1% bentonite decreases the iron content by about 7 kg/ton of iron product [5]. In addition, an increase in the silica content of the pellet charge leads to an increase in the cost of steel production [6]. In the case of direct reduced pellets, every percent of acid gangue addition is associated with an increased energy consumption of 30 kWh/ton [7].

Organic binders may offer a viable alternative to bentonite as they burn out at high temperatures during the thermal process with virtually no residue. Numerous laboratory, pilot and industrial scale studies have been conducted on the use of organic binders to replace bentonite. All the studies had one particular result in common. That is, while compressive strength of wet and dry pellets produced with organic binders were as good as or better than those produced with bentonite, the strengths of pre-heated and fired pellets were insufficient. These findings have been related to the lack of slag film bonding introduced by bentonite [4,5,8,9]. Pre-heated pellet strength is particularly important in the grate–kiln–cooler pellet induration system. If the pre-heated compressive strength of pellets is insufficient, pellets will be disintegrated on the travelling grate and in the rotary kiln. As a result process equipment and refractory lining will be damaged by the pellet dust formed and carried in gas streams. If the problem is not rectified within a reasonable span of time, plant operation may be interrupted and the efficiency in terms of productivity and quality will decrease. The fired pellets with low strength give rise to losses as a result of the production of unwanted fines or dust during process, storage and transport. In addition, fines also cause operational difficulties in reduction furnaces. Therefore, organic binders have not found widespread application in the industry.

Colemanite, a Ca-borate salt, has a chemical formula $2CaO_3B_2O_3.5(H_2O)$ with a melting point of 986 °C [10] and forms boro-silicate bonding at relatively moderate temperatures (approximately 1000 °C) in the presence of silica in the iron ore. In consequence formation of such structures is expected to contribute to the strength of the pellets through slag bonding [1]. Absence of acidic impurities and alkalis in colemanite combined with low melting temperature, good thermal and mechanical properties of boro-silicate bonding favors the use of colemanite as a slag forming constituent in the binder mix of organic binder and colemanite. While colemanite provides the required strength to the pre-heated and fired pellets, the wet and dry pellets attain their strength through organic binders. Such a combination can, therefore, be used in place of bentonite in iron ore pelletization.

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Table 1
Chemical composition of magnetite concentrate and sodium-bentonite.

Constituents, %	Magnetite concentrate	Sodium-bentonite
Fe	69.25	2.92
SiO_2	0.95	67.76
Al_2O_3	1.40	16.86
CaO	0.53	2.19
MgO	0.90	3.62
Na_2O	0.05	1.38
K_2O	0.14	0.73
S	0.48	0.59

2. Materials and methods

2.1. Materials

The magnetite concentrate obtained from Divriği Concentration Plant located in Divriği-Sivas, Turkey. The as-received magnetite sample was washed with tap water repeatedly, filtered and dried at 105 °C overnight. The dry concentrate was split into representative test samples of 500 g according to ASTM E 877-03 [11] and stored in plastic bags for pelletization experiments. This magnetite concentrate had a 1617 cm^2/g Blaine number, 65.3% by weight −45 μm (325 mesh) material and a density of 5.1 g/cm^3.

The sodium-bentonite binder was from Reşadiye-Tokat, Turkey and had a particle size of 90% by weight −74 μm (200 mesh) material. The chemical composition of magnetite concentrate and sodium-bentonite were determined with X-ray fluorescence (XRF) spectrometer and given in Table 1.

Colemanite concentrate was obtained from Eti Mine Bigadiç Concentration Plant at Balıkesir, Turkey. The colemanite concentrate contained 43% B_2O_3, 6.5% SiO_2, 26% CaO, and 0.5% SO_3. The as received colemanite concentrate was washed, dried and crushed to −1 mm (16 mesh). This sample was calcined at 550 °C for 1 h to remove chemically bonded water. Calcined colemanite (CC) with a density of 1.95 g/cm^3 was ground to 85% by weight −45 μm in a centrifugal ball mill.

Technical grade CMC, food grade corn starch and Ciba DPEP06-0007 (a binder specifically produced for iron ore pelletization) were tested as organic binders. The former two were purchased from the local market; the latter was provided by Ciba Specialty Chemicals Holding Inc.

2.2. Equipments

Elemental analyses of magnetite concentrate and bentonite were carried out using Spectra IQ X-ray fluorescence (XRF) spectrometer. The specific surface area of magnetite fines was measured with a Blaine air permeability apparatus as described elsewhere [12]. Pelletization experiments were performed in a 39 cm diameter by 10 cm depth laboratory-scale balling disc. The rotational speed of the balling disc was set to 11 rpm and tilt angle of the disc bottom to 60°. A Laboratory drying oven and a muffle furnace with a heating rate 5 °C/min were used to dry the wet pellets and fire the dry pellets. The dimensions of the heating chambers W×D×H in cm were 45×40×65 and 30×55×15 for drying oven and muffle furnace, respectively. Compressive strengths of the pellets were determined according to ASTM E 382-07 [13] using a mechanical press with a 5000 kg load cell and 1 kg of accuracy at a constant cross-head speed of 10 mm/min. Rigaku Miniflex II X-ray diffractometer (XRD) was used for the mineralogical analysis and JEOL JSM-6400 scanning electron microscopy (SEM) was used to take micrographs of pellets.

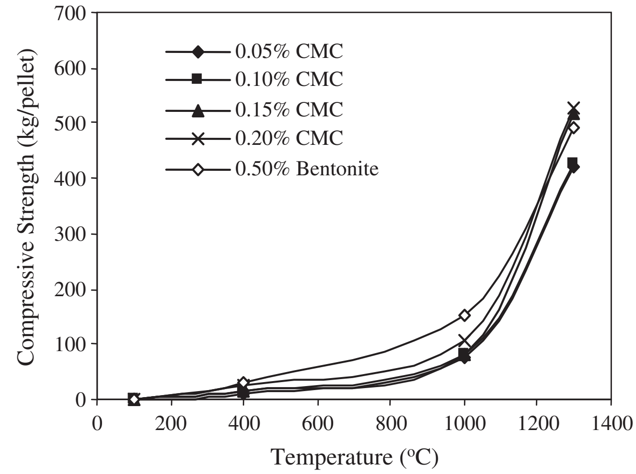

Fig. 2. Compressive strengths of pellets produced with CMC.

2.3. Pelletization tests

Moist feed for the pelletization experiments was prepared by mixing 1000 g of dry magnetite concentrate and the required amount of water and binder (bentonite, organic binders and calcined colemanite alone or in combination). The moist feed was then rubbed through a 1.68 mm (10 mesh) screen. 200 g of moist feed was put into the pelletizing disc to form pellet seeds. Water mist was applied onto the material to facilitate the seed production. Following the production of pellet seeds, the rubbed material was gradually fed to

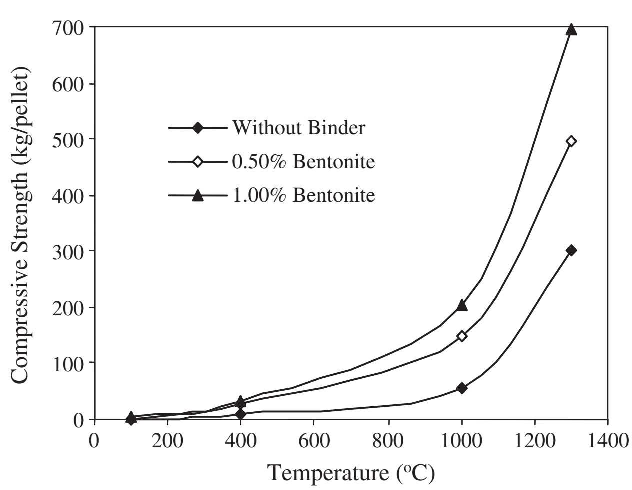

Fig. 1. Compressive strengths of pellets produced with bentonite.

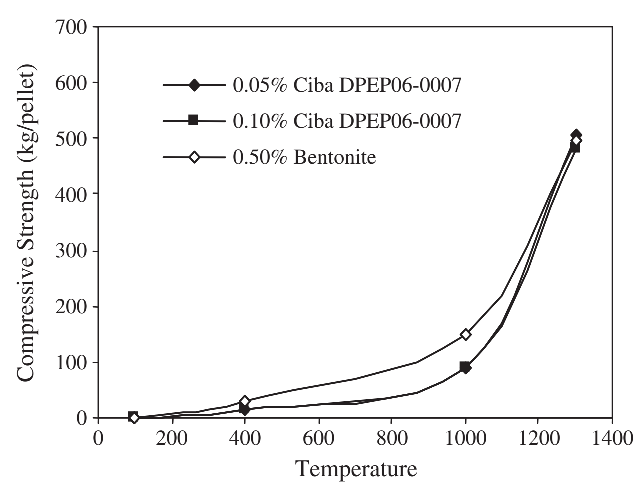

Fig. 3. Compressive strengths of pellets produced with Ciba DPEP06-0007.