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Effect of cetyl trimethyl ammonium bromide on shrinkage cracks in filter cakes during pressure filtration of iron ore concentrates

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ABSTRACT

During the dewatering process of iron ore concentrates, the formation of shrinkage cracks severely interferes with the filtration process and causes high cake moisture. Until now, effective countermeasures and mechanism study about shrinkage cracks are still insufficient. In the previous researches, capillary forces have been considered to be the driving potential for the shrinkage cracks, which were related with liquid surface tension and particle contact angle. Thus, surface tension and contact angle were both changed in this paper by using a cationic surfactant, cetyl trimethyl ammonium bromide (CTAB). Moreover, the zeta potential, adsorbance and infrared spectra were respectively measured before and after CTAB coating to analyze the change of interfacial properties and the influence on the extent of shrinkage cracks. The results indicate that the tendency of filter cakes to form shrinkage cracks can be weakened with the decrease of capillary forces.

1. Introduction

During the filtration process of fine ore, such as aluminium tailing, zinc sulfide, limestone etc., the undesirable shrinkage cracks (as shown in Fig. 1) of filter cakes usually occur, which is a common problem in dressing plants and negatively affect the filtration process, through increase of gas consumption and breaking chamber pressure. The sequence is obtaining higher cake moisture due to the early termination of dewatering. However, the cracks problem hasn't gained enough attention and is usually treated as a normal phenomenon. Thus, limited countermeasures have been proposed up to now and the conventional methods include adding rollers, pressure taps and fiber filter aids.

The shrinkage cracks are always formed in the dewatering stage of filtration process and spread through the depth of filter cakes down to the filter cloth, whereby the finer the suspension particles and the more distinct the compressibility of the filter cake, the higher is the cracking probability [1–3]. After the formation of filter cake, water is drawn off from bundle of capillaries continuously if gas differential pressure is large enough to overcome the capillary forces [1]. Shortly after the gas contacts with the top surface of wet filter cake, the meniscus is formed and capillary forces arise. Fig. 2 schematically illustrates capillary forces between particles, which is called liquid bridge model. Capillary forces consist of adhesive forces (F_A) and capillary suction (F_C). If the tensile strength determined by the weakest liquid bridges can't withstand the stresses arisen from capillary forces, the shrinkage cracks occur [2,4].

H. Anlauf et al. [1] studied the influence of operational conditions on the crack formation, such as cake height, filter area geometry, pressure difference, filter area and filter medium. Thomas Wiedemann et al. [2] researched the effect of compressive pressure on the extent and the course of shrinkage process. They all propose the liquid bridge model and consider that capillary forces are responsible for the crack formation. However, they haven't carried out a deep research about the influence of capillary forces on the cracks, which restricts the mechanism study about the formation of shrinkage cracks.

The liquid bridge is usually considered to be a toroidal shape and the Gorge method can be used to calculate capillary forces [5], which can be expressed as followed [6,7]:

$$F_{cap} = \pi\gamma R^2 \sin^2\beta\left(\frac{1}{r}-\frac{1}{l}\right) \approx 2\pi\gamma R\cos\theta\left(1-\frac{D}{2r\cos\theta}\right) \quad (1)$$

Where, γ is liquid surface tension, N/m; θ is the solid/liquid contact angle of particles, °.

According to Eq. (1), capillary forces are proportional to liquid surface tension (γ) and contact angle (θ). Because capillary forces are the root cause for shrinkage cracks, reducing capillary forces means decreasing liquid surface tension and increasing contact angle. It is the key to avoid or reduce shrinkage cracks.

Surfactants are used to change the interfacial properties of solution obviously with a small addition. In particular, surfactants can decrease the solid/liquid interfacial tension and weaken the grain wettability. In

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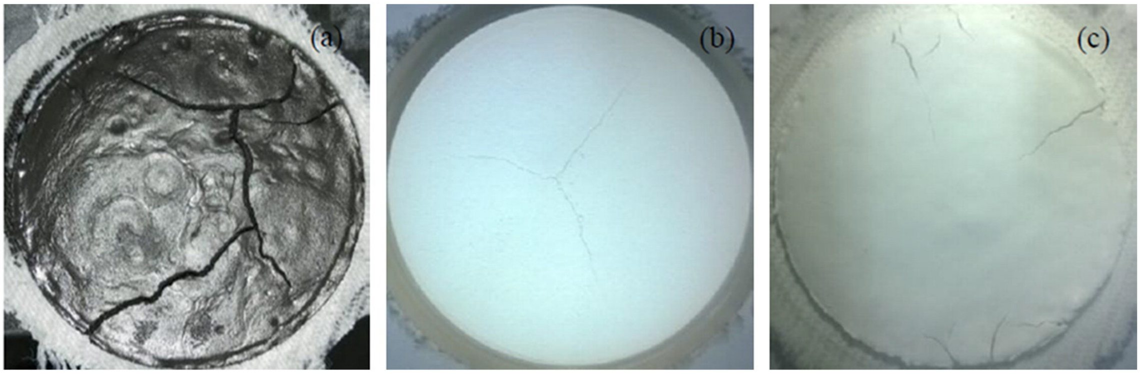

Fig. 1. The shrinkage cracks of (a) iron ore concentrates, (b) limestone and (c) barite during pressure filtration.

this study, roasting-low intensity magnetic separation (LIMS, for short) iron ore concentrates were chosen as the bench-scale experimental materials since the quite serious crack problem in the industrial production, which even forced the filters shut down. As the negatively charged LIMS iron ore concentrate particles, a cationic surfactant, cetyl trimethyl ammonium bromide (CTAB), was chosen as an absorbate to improve the interfacial behaviors of ore pulp. Cake compressibility index (n) was calculated to evaluate the cracking probability. The effects of CTAB initial concentration on the surface tension of filtrate, zeta potential and contact angle of iron ore concentrate particles were studied to reach a minimum of capillary forces. The FTIR was tested to research the adsorption mechanism of CTAB on the sample particles.

2. Materials and methods

2.1. Materials and reagents

LIMS iron ore concentrates were obtained from Jingtieshan Iron Mine of Jiuquan Steel Company in Gansu Province of China. They were treated by roasting, crushing, grinding, screening, classification, magnetic separation, flotation and concentration, etc. XRD patterns of raw ore and roasted sample were shown in Fig. 3. It indicated that raw ore mainly consisted of specularite, siderite, goethite and the gangue minerals were primarily quartz and dolomite, while less mineral compositions existed in the roasted sample, mainly containing magnetite and quartz. Main chemical compositions of LIMS iron ore concentrates were analyzed and presented in Table 1. The pH of ore pulp was approximately 10.0. The iron ore concentrate particles were dryly grinded to a relatively smaller size fraction with a volume average particle diameter of 0.031 mm. The BET surface area and the average pore diameter determined by N_2 gas adsorption method were respectively 8.12 m^2/g and 12.9 nm when the size of chosen sample particles ranged from 0.025 mm to 0.045 mm. Distinctly, the specific surface area of sample particles was much larger than which of the same size fraction [8]. This is because the raw ore of Jingtieshan Iron Mine contained quite a few siderite ($FeCO_3$) and limonite ($2Fe_2O_3 \cdot 3H_2O$), when lump ores were roasted in shaft furnace under high temperature, mineral crystal lattice would release carbon dioxide and vapor, resulting a large number of pores and fissures formed on the surface and interior of iron ore and a further expansion of original micropores.

Analytical reagent surfactant CTAB was supplied by Guangfu fine chemical institute of Tianjin. 1 g/L CTAB aqueous solution was prepared as stock solution using deionized water and diluted to the required concentration.

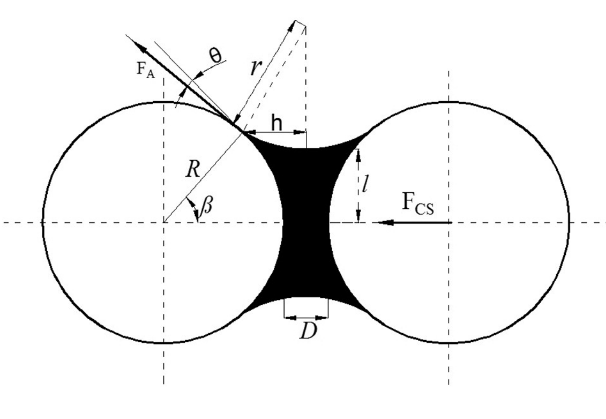

Fig. 2. Schematic illustration of liquid bridge model.

2.2. Methods

2.2.1. Cake compressibility index (n)

The average specific cake resistance (represented by α_{av}) of iron ore concentrates filter cake was calculated by measuring the volume of filtrate as a function of filtration time at differential pressures 1.5 bar, 2 bar, 2.5 bar and 3 bar. The relationship between the average specific cake resistance and cake compressibility index (n) could be characterized by Eq. (2) [9–13]

$$\lg\alpha_{av} = n\lg\Delta p + \lg\alpha_0 \tag{2}$$

Where, α_o is the specific cake resistance at unit pressure drop, m/kg; Δp is the pressure drop across the filter cake and filter medium, Pa.

Eq. (2) showed a linear relation between $\lg\alpha_{av}$ and $\lg\Delta p$, and thus n could be obtained from the slope of a plot of $\lg\alpha_{av}$ versus $\lg\Delta p$.

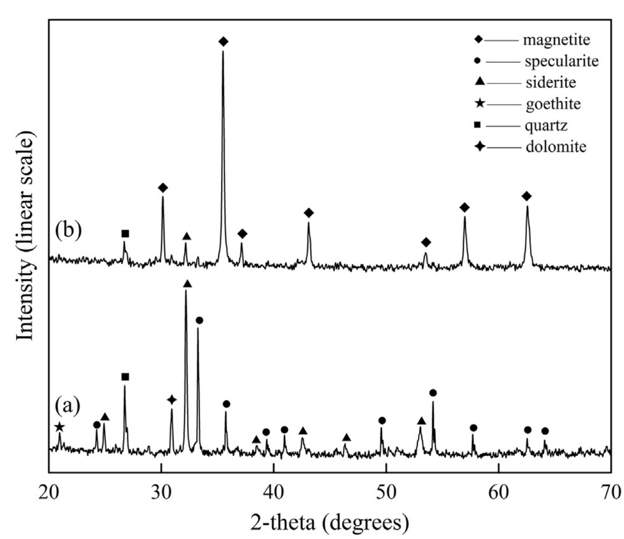

Fig. 3. XRD patterns of (a) raw ore and (b) roasted sample.