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Fine coal circuitry considerations in treatment of soft coal with difficult washabilities

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Abstract

A typical process used in Chinese metallurgical coal preparation plants employs heavy-media separation to treat the coal coarser than 0.5 mm. The −0.5 mm fine coal is treated with froth flotation. A major disadvantage of this process is that a large quantity of fine coal is recycled in the heavy-media cyclone circuit, which results in high magnetite losses. The −0.5 mm fine coal in the media is a result of poor raw coal deslime screen efficiency and the continuous breakage associated with the processing of soft coal. Another disadvantage of this typical process is that some coarse clean coal particles are lost to the froth flotation tailings. This investigation focuses on the simulation of processing fine soft coal with water-only cyclone (WOC) and spirals. WOCs and spirals have become popular devices for treating fine coal. WOCs can operate at low specific gravity cut points to produce low ash clean coal while spirals tends to operate at high specific gravity cut points and act as a scavenger to rewash the underflow (refuse) from WOCs. The combination of WOCs and spirals can compete with a heavy-media cyclone with respect to both efficiency and clean coal yield when treating 1 mm × 100 Mesh fine coal. This fine coal processing circuit can subsequently increase the bottom size of the heavy-media cyclone feed from 0.5 mm to 1 mm which will reduce the loading of the heavy-media cyclone circuit. This change in circuitry thus reduces magnetite consumption without scarifying separation efficiency of the 1 mm × 0 size fraction. Furthermore, the reduction of the nominal top size of the froth flotation feed from 0.5 mm to 0.15 mm will greatly decrease or eliminate the loss of clean coal to flotation tailings.

Keywords: Coal; Gravity separation; Simulation; Fine particle processing

1. Introduction

1.1. Importance of fine coal circuits

ROM (Run of mine) coal is following a trend toward increased −1 mm fine coal. The increasing use of continuous miners underground aggravates this problem in that these machines commonly produce a raw coal with 50% or more of the solids being finer than 6.35 mm. Magnetite losses in a heavy-media cyclone increase as the quantity of fine coal in the feed increases. This is due to the increasing specific surface area of fine particles. Fine clean coal also has much higher surface moisture than coarse clean coal. The subsequent increase in the surface moisture of the overall clean coal product negatively affects sale prices. Fine coal processing also consumes large quantities of reagents such as flocculants, as well as collector and frothers when froth flotation is utilized. The usage of these chemicals might not only increase the operating costs, but may also cause environment concerns. Therefore, when fine coal consists of a large percentage of the raw coal feed, careful consideration must be taken into the selection of fine coal circuits whose separation efficiency will have a heavy impact on overall plant performance. For the fine coal studied in this investigation, the flotation performance is poor due to the surface oxidation during storage and coarse coal losses in the flotation tailings. The flotation test results (0.5 mm × 0) show a clean coal yield of 57% with a clean coal ash of 12.0% and the flotation tailing ash content is as low as 36.65%. An alternative to processing this 0.5 mm × 0 fraction with froth flotation is to use gravity separators, such as water-only cyclones and spirals.

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1.2. The functions and performance of water-only cyclone (WOC)

The generalized WOC separator consists essentially of a cylindrical column with a short conical bottom. Typically, 15 in. (350 mm) diameter WOCs are used effectively in preparation plants to wash the 1 mm × 0.15 mm raw coal. Raw coal (1 mm × 0) slurry enters the cyclone tangentially through an inlet in the upper part of the cylindrical column. Refuse particles accumulate in the cone of the cyclone and create a dense bed of particles above the apex of the cyclone, which makes the WOC a gravity separator rather than a classifier. Clean coal (the cyclone overflow) leaves through a central vortex finder pipe and the refuse able to penetrate the dense bed of particles is discharged through the apex. In general, the major operating variables of the WOC include the geometry of cyclone (cyclone diameter, ratio of vortex finder to apex diameter, vortex finder length, and apex size), solid concentration of the feed, and inlet pressure.

WOC shows many advantages in fine coal processing, theses benefits include: no moving parts; low operating costs; specific gravity cut points as low as 1.26; very low ash clean coal without the use of heavy media; does not require pre-screening and thus all −1 mm fine coal can be fed directly to the WOC; efficiently clean oxidized raw coal and removes free pyrite down to 100 mesh, whereas flotation will not; and requires little space for operations [1,2].

1.3. The functions and performance of spirals

The use of spiral separators in the treatment of fine coals is now a popular option in fine coal circuitry design. Spiral can be effectively clean 1 mm × 0.15 mm coal at very low operating costs. Unfortunately, due to the classification effect of particles in flowing films, spirals tend to have a high specific gravity cut point (1.7 to 2.1) and misplace significant amounts of high ash fines into the clean coal. The specific gravity cut point can be reduced, but it is not economical because the feed rate to spiral must then be greatly reduced [3,4]. The separation efficiency of a spiral is also worse than that of a heavy-media cyclone when cleaning 1 mm × 0.15 mm coal. Spirals are often used as a scavenger in multi-stage circuits to rewash the refuse from WOCs [5]. From a process design viewpoint, it is clearly advantageous to be able to forecast the results of the selection of fine coal circuitry. Different fine coal circuits were compared and the separation performance computed and predicted in this investigation.

The objectives of this investigation were to maximize the separation efficiencies in the fine coal circuits, to decrease the magnetite loses in the dense media cyclone circuits, and to eliminate the coarse clean coal lost to the flotation tailings. Specific aims were to:

1. Quantify and determine the cause of significant magnetite losses in the heavy dense medium cyclone circuit;
2. Quantify the coarse clean coal lost in traditional flotation process;
3. Simulate the separation performance of different fine coal circuits;
4. Quantity the contributions of new WOC–spiral fine coal circuits to the existing heavy-media cyclone circuit;
5. Increase the plant capacity by the addition of a new fine coal circuit.

2. Analysis of existing flowsheet

2.1. Existing flowsheet

The flowsheet for treating 13 mm × 0 coal in the Qianjiayin coal preparation plant is shown in Fig. 1. The plant feed (13 mm × 0) is fed to raw coal banana screens with a 0.5 mm deck aperture. The +0.5 mm coal feeds the primary heavy-media cyclone (HMC) circuit. The primary HMC refuse is rewashed in the secondary HMCs to produce middlings and refuse products. The misplaced 0.5 mm × 0.3 mm fine clean coal is recovered from the primary magnetic separator tailings by a bank of classifying cyclones; the classifying cyclone underflow flows to a bank of sieve bends. The sieve bend oversize is discharged into fine clean coal centrifuges. The raw coal deslime screen undersize (0.5 mm × 0), the classifying cyclone overflow, and the sieve bend undersize feed the froth flotation cells. The flotation concentrate is dewatered by a bank of vacuum filters. The flotation tailing is pumped to a bank of classifying cyclones to recover the lost coarse clean coal particles from trapped in the flotation tailings. Coarse clean coal is lost to the flotation tailings due to the poor kinetics associated with floating coarse particles. The underflow from the classifying cyclone flows to a bank of screen bowl centrifuges. The fine coal centrifuge and vacuum filter effluents recycle to the flotation cells. The screen bowl centrifuge effluents, which consist of high ash fines, flow to the refuse thickener. The thickener underflow is dewatered with frame filter presses.

2.2. Raw coal washabilities

The expected feed to the preparation plant is Seam 5#, 9# and #12. The analysis of the washability characteristics of these coals indicate that a separation specific gravity of 1.50 is required to achieve a primary product target ash content up to 11.0%. This coal is very difficult to wash because the amount of near gravity material (+/−0.1 SG units) consists of 20–25% of the feed. Typical coal preparation plants operating at a 1.50 specific gravity can efficiently process down to 1 mm in a single heavy-media cyclone. Float-sink test results of the feed, clean coal product, and refuse sampled from the 840 mm diameter heavy-media cyclone were used to generate the partition curves for different size fractions processed in the heavy-media cyclone (Fig. 2). The data was collected when processing 670 metric tons per hour (MTPH) of 13 mm × 0.5 mm feed. Fig. 2 illustrates how separation efficiency in the heavy-media cyclone (HMC) decreases as the feed particle size decreases, which is in agreement with the results from other investigators [6]. As shown in Table 1, for a 13 mm × 1 mm coal, if the particles are relatively coarse, a good separation can be