PRELIMINARY RESULTS FROM A CROSS-FLOW FLOTATION COLUMN FOR ENHANCED PYRITIC SULFUR REJECTION FROM COAL

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ABSTRACT

This paper describes the design and operation of a mechanized cross-flow flotation column (CFC) for fine coal cleaning. In a CFC, a series of helical inserts is attached to the wall of a conventional column to function as a pyrite particle (high density particle) retardant. The coal slurry is stirred in the column by impellers attached to a central shaft. A series of flotation tests was run in both a CFC and a conventional column to compare the kinetics of clean coal recovery and the rejection of pyritic sulfur. The CFC not only provided a better rejection of pyritic sulfur, but also provided a higher coal recovery and better flotation kinetics, i.e., the asymptote of the Btu recovery curve was higher and the recovery of clean coal was faster than that obtained with the conventional column.

INTRODUCTION

Froth flotation is a primary solid-solid separation process for fine particles. The process has been widely practiced for almost a century in the mining industry for concentrating valuable minerals and for cleaning fine coal[1,2]. Traditionally, a majority of the coal in the U.S. is cleaned at coarse and intermediate sizes (down to 28 mesh) by gravity separation, and a significant portion of the fines (minus 28 mesh) are discarded as waste into tailings ponds. In the U.S., only about 5 percent of fine coal is cleaned by froth flotation because of technical difficulty and unfavorable economics. For coarse coal cleaning, the technology is well established and thus needs less attention. However, the processing of fine coal is known to be difficult and requires substantial technological improvements. Typically, fine coal processing by flotation is associated with difficulties in froth handling, product dewatering, low throughput, and inefficient separation of pyrite [3].

This paper discusses the development of a high-efficiency mechanical column to improve pyritic sulfur removal from fine coal. The development is necessary to reduce the wasteful discharging of fine coal to tailings ponds, with the benefits of lower costs, improved energy recovery, and removal of pyrite as an SO_2 air pollution precursor.

Fine coal cleaning depends not only on the surface properties of coal and mineral matter but also on their specific gravity. There are three major component groups in raw coals: coal, clay minerals, and pyrite.

Flotation is effective in clay removal but has difficulty in separating coal from pyrite, as illustrated in the following test results for an Upper Freeport seam coal in a 2" conventional flotation column [4].

Size Fraction	Feed, wt.%		Clean Coal, wt.%	
	Ash	Pyr. Sulfur	Ash	Pyr. Sulfur
Topx200M	27.3	1.7	13.4	1.2
200Mx400M	20.1	2.2	11.7	2.1
400Mx0	27.8	1.6	12.4	1.7
Total	25.7	1.8	12.5	1.6

The above table indicates that while the ash (clays) removal by a traditional column is rather effective, from 20.1-27.8% range down to 11.7-13.4% range, the pyritic sulfur removal is not effective. Total reduction of ash (clay) is 51%, while the total reduction of pyritic sulfur is only 8%. The main drawback for the flotation process is that it is difficult to separate coal from pyrite because both species possess similar surface hydrophobicity. Such similarity makes fine coal cleaning difficult.

To separate coal from pyrite (and other heavy metals and minerals), it is desirable to take advantage of the large difference in their specific gravities: the specific gravity of coal is 1.2, while the specific gravity of pyrite is 5.0. To take advantage of this fact, a modified flotation column that utilizes centrifugal force to effect the separation of pyrite from coal was designed and tested.(Note: Clay has a specific gravity of 2.6. Because of the smaller difference in specific gravity, the separation of clays from fine coal by gravity methods is not as effective as that of flotation.)

DESCRIPTION OF THE COLUMN

The laboratory CFC is 4 inches in diameter and 4 feet in height. In a CFC, a series of angular helical inserts is attached to the wall of a conventional column to function as pyrite particle retardants as shown in Figure 1. During flotation, coal slurry is mixed with a series of impellers attached to a central shaft. The pitch of the impellers is at 45 degrees. This helps to create a string of vortices near the shaft during the mixing. The slurry is moved in a circular motion by stirring in a counter-clockwise direction and is moving slightly upward, while the helical insert is arranged in a clockwise direction and is slightly downward.

During flotation, air bubbles are generated from the bottom of the column. The clean coal forms a light-weight froth through the attachment of coal particles to the rising air bubbles. The froth, due to its relatively light weight, is concentrated near the center of the shaft and moves upward. The heavy pyrite, due to its high specific gravity, swirls along the wall of the column and is caught by the angular helix. The pyrite is washed downward along the helix by the movement of water.

OPERATION OF THE COLUMN

Figure 2 shows the flowsheet of the flotation column circuit. In the flotation operation, air bubbles are generated with three air spargers located in the bottom chamber at 14 psig air pressure. A variable speed motor is used to turn the mixing impeller. The impeller speed was set at 1400 rpm for all the tests. Experiments were carried out in a semi-continuous mode. In each test, 300 grams of coal were pre-mixed in a 1500 mL beaker with an addition of 500 mL tap water. The coal and water mixture was conditioned for 5 minutes with an addition of variable amounts of methyl isobutyl carbinol (MIBC) frother. The column was filled with 9 L water, and then the pre-conditioned coal slurry was charged into the column for flotation. Clean coal froths were collected at various predetermined time periods until depletion of the froth.

An Upper Freeport coal from Indiana County, Pennsylvania was used in this study. The sample was stage crushed and screened to collect the 100M x 325M size fraction for experiments. The feed sample contained 26.4% ash and 2.9% sulfur (2.4% pyritic sulfur, 0.06% sulfate sulfur and 0.5% organic sulfur). The effect of frother concentration on the kinetics of coal recovery and the removal of pyrite was evaluated.

RESULTS AND DISCUSSIONS

A series of column flotation experiments was run to compare the kinetics of coal cleaning using three modes of operation: (1) without mixing and without helix attachment, (2) with 1400 rpm mixing but without helix attachment, and (3) with helix attachment and 1400 rpm mixing. Figure 3 shows cumulative Btu recovery as a function of time for each of the above three flotation modes. The column with helix attachment and with mixing has superior recovery and superior kinetics. A kinetic analysis was performed using techniques described by Lai et al. [5]. The asymptotes of the cumulative recovery curves are 90.6, 87.3, and 78.0 for modes 3, 2, and 1 respectively. Figure 4 shows the kinetic plots for the three modes of operation. Mode 3 exhibits the highest rate as exemplified by the steepest slope.

Several tests were conducted to compare the pyritic sulfur rejection capabilities of the CFC column with those of more conventional flotation techniques (Denver cell and the open column). The results are shown in Figure 5. Figure 5 indicates that the CFC achieved higher pyritic sulfur rejections than the other flotation systems, at all levels of frother concentration. The Denver cells had the poorest pyritic sulfur rejections, most likely because of the turbulent flotation conditions present in a Denver cell, which results in significant entrainment of unwanted mineral matter.

In the first phase of CFC development, there was no froth washing mechanism installed in the column. This is because we have limited our effort to the separation of pyrite without emphasizing the removal of clay. However, in the second phase of development, we will incorporate a wash water system to reduce clay contamination in the froth and achieve deeper cleaning of the coal. To do this, an 18-ft column is being constructed. In this development, a 6-ft section of froth washing will be included.

CONCLUSIONS

The Cross-Flow-Column (CFC) is a mechanized column for fine coal cleaning. Preliminary results indicate that the CFC not only has potential application for enhanced pyritic sulfur rejection from coals but also has potential for providing higher coal recoveries at shorter residence times, i.e., the asymptote of the Btu recovery curve is higher and the recovery of clean coal is faster than that obtained with conventional column flotation. In addition to coal, the CFC may also find application in the beneficiation of other minerals, including iron ores, sulfide ores, and phosphate minerals.

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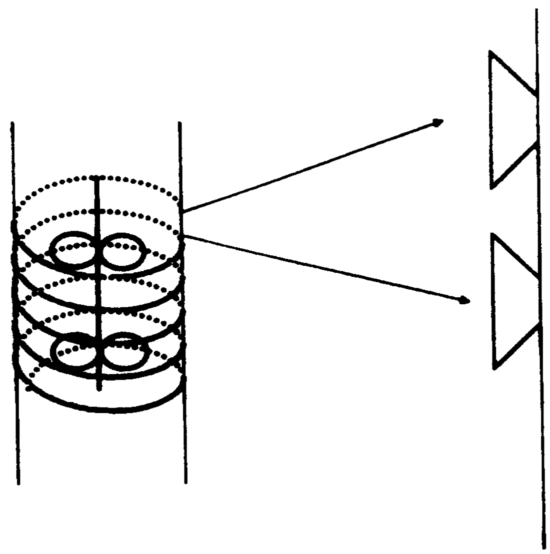

Figure 1 Attachment of angular helical inserts

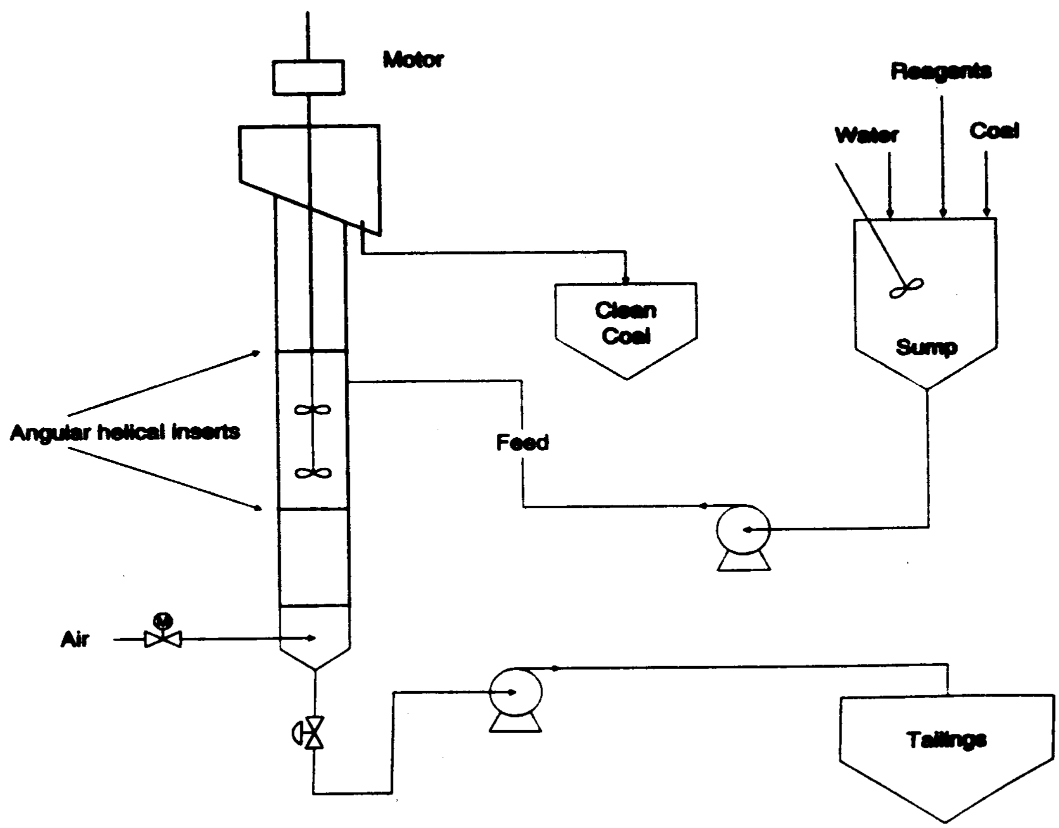

Figure 2 Flowsheet of column flotation circuit

Fig. 3 Kinetics of Clean Coal Recovery

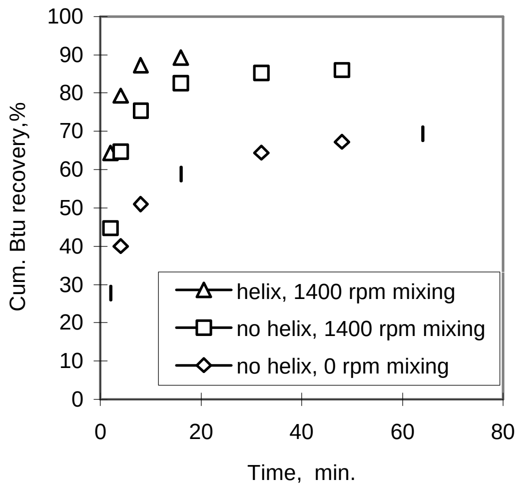

Fig. 4 Proportionality plot

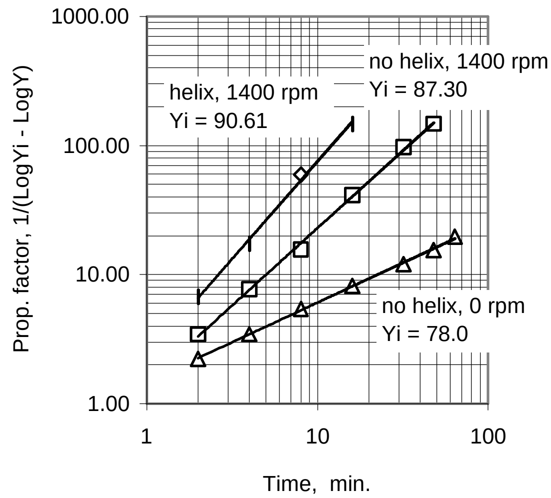

Fig. 5 Pyritic sulfur rejection vs. Btu recovery