Recovery of clean coal from polymer flocculated raw coal slurry

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Abstract

The recovery of fine clean coal from waste streams using column flotation is recognized as an efficient and economical technique. However, due to the low percent solids (~3% by weight) found in these fine waste slurries, the flotation columns have low capacities and are, thus, underutilized. In this study, a 3% (by weight) solids suspension of Upper Freeport coal was flocculated with polymers and concentrated to 10% (by weight) solids. The flocculated slurry was then floated using 250 g/t No. 2 fuel oil and 250 g/t MIBC, which provided a clean coal with 12% ash at an 80% yield. The results showed that flocculated coal could be floated effectively. Zeta potential and contact-angle data showed that the presence of polymer on the surface of the coal did not affect its hydrophobicity, and in some cases it improved the hydrophobicity as indicated by larger contact angles.

Key words: Fine coal recovery, Column flotation, Waste streams, Floculation, Polymers

Introduction

In the last decade, utilization of column flotation for the recovery of fine coal has gained considerable momentum. A number of scientific papers have been published related to the column flotation of fine coal. Parekh et al. (1989) described the results obtained with commercial-scale "Ken-Float" columns at the Powell Mountain Coal Company. Yoon et al. (1992) presented results of pilot-scale and commercial-scale column flotation units. All of the results clearly indicated that column flotation is effective in obtaining a low-ash clean coal at high combustible recovery.

In coal-preparation plants, column flotation is used to process fine (-150-μm) material. In many of the plants the amount of solids present in this fine stream varies from 2% to 5% (by weight). For example, at the Powell Mountain Coal Company in St Charles, Virginia, a 2.4-m- (8-ft-) diam, 6-m- (22-ft-) high column processes about 63 L/s (1,000 gpm) of slurry containing about 3% (by weight) solids. The column is capable of processing slurries up to 10% (by weight) solids. Therefore, the columns are being underutilized. At present, coal companies do not have the flexibility to increase the solids contents of the fine slurries. Coal companies have expressed an interest in determining whether the fine coal slurry could be flocculated and concentrated to about 10% (by weight) solids and then floated to utilize the column's high capacity.

This paper describes results obtained on flocculation of coal fines followed by floatation using conventional reagents and machines.

Experimental

For this study, the Upper Freeport seam coal was first crushed to 60 mesh and then ground to 80% passing 325 mesh (45 μm) using an attritor mill. Froth flotation tests were conducted using a laboratory Denver Flotation Machine, Model D-12. Fuel oil No. 2 and methyl isobutyl carbinol (MIBC) were used as collector and frother, respectively. For all the flocculation/flotation tests, a 3% (by weight) solids suspension of the fine ground coal was flocculated using 0.1% stock solution of the polymers. The flocculated solids were separated from the supernatant and concentrated to about 10% (by weight) solids. About 100 g of concentrated flocculated solids were used for each flotation test. Table 1 lists the polymer flocculants used in the study. The flotation concentrate and tailings were analyzed for ash and sulfur using standard ASTM techniques. The pH of the slurry was close to 8.0. The contact angle studies were conducted using the Rame-Hart Inc. Goniometer, Model 100, and the zeta potential studies were conducted using the Zeta Meter, Model 3.0.

Results and discussion

Table 2 lists the proximate analysis of the Upper Freeport Coal used in the studies. Note that it contained about 26% ash. The baseline flotation data on the unflocculated coal slurry using 10% (by weight) solids with various dosages of MIBC and fuel oil showed that by using 250 g/t fuel oil and 250 g/t MIBC a clean coal containing about 8% to 10% ash at an 80% yield could be obtained (Parekh and Brauch, 1999).

Nonmeeting paper number 03-313. Original manuscript submitted for review May 2003. Revised paper received and accepted for publication July 2004. Discussion of this peer-reviewed and approved paper is invited and must be submitted to SME Publications Dept. prior to May 28, 2005.

Table 1 — List of flocculants used.

Magnifloc 494C	cationic
Superfloc 16	nonionic
Superfloc 204	anionic

Table 2 — Proximate analysis of the Upper Freeport Coal.

Moisture	4.01%
Ash	25.65%
Volatile matter	20.05%
Fixed carbon	50.30%
Total sulfur	2.59%
Pyritic sulfur	1.24%
Sulfate	0.95%
Organic sulfur	0.40%
Heating value, Btu/lb	10,331

It was found that complete flocculation of all suspended particles in the coal slurry was obtained with all three flocculants. A clear supernatant was obtained within two minutes after the addition of either 2-ppm anionic or 20-ppm nonionic or 2-ppm cationic flocculant.

Figure 1 shows the flotation data of the slurry flocculated with various dosages of the cationic flocculant. Note, that the heating value (Btu/lb) recovery declines from 99% to 80% with increases in flocculant dosage from 0 to 12 ppm. The ash content of clean coal increases slightly from 12% to 15% with increase of the flocculant dosage. It is speculated that higher amounts of flocculant formed large flocs that trapped some ash particles. The sulfur content of clean coal did not change significantly with increasing flocculant dosage.

Figure 2 shows the effect of anionic flocculant dosage on heating value recovery, sulfur and ash content of the clean coal. As mentioned above, with this flocculant a dosage of 15 ppm or higher was required to achieve flocculation of fine particles. Note that using 15-ppm flocculant, the heat recovery was about 95%. However, the ash content was 15%, which is a little higher than that obtained with the cationic flocculant. The sulfur content of the clean coal increases with increase in flocculent dosage.

Figure 3 shows the effect of nonionic flocculant dosage on the flotation of the coal. Note that the heating value recovery remains about 95% up to 4 ppm, and then it reduces to about 89% as the dosage of flocculant increases to 6 ppm. The ash and sulfur content of clean coal remains more or less constant.

In coal processing plants, the use of anionic flocculant is prevalent. To understand the surface chemistry of the coal flocculated with anionic flocculent, zeta potential and contact angle studies were conducted. Figure 4 shows the zeta potential of the coal in the presence of various dosages of the anionic flocculant with respect to pH. It shows that the negative charge on the coal particles increases with increase in the flocculant dosage reaching maximum at about pH 9.0. Figure 5 shows the contact angle data of the coal at various concentrations of the anionic flocculent with respect to pH. Note that the contact angle increases with increase in pH, reaching a maximum at around pH 9.0, the same pH at which the zeta potential reached maximum. Osasere (2000) reported similar results. Osasere (1998) reported that the limiting maximum value of contact angle as well as high recovery of coal at pH

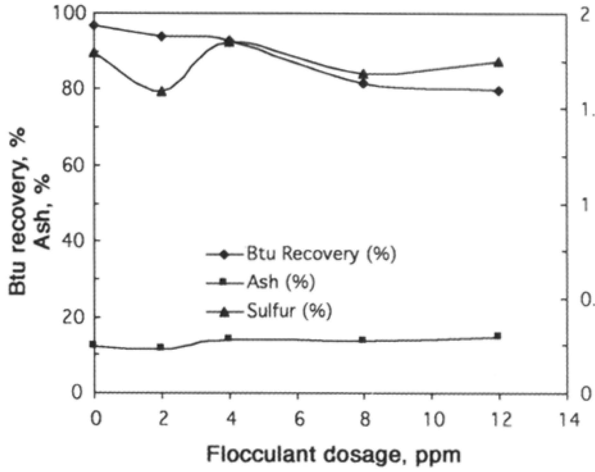

Figure 1 — Effect of cationic flocculant dosage on Btu recovery, ash and sulfur contents of clean coal.

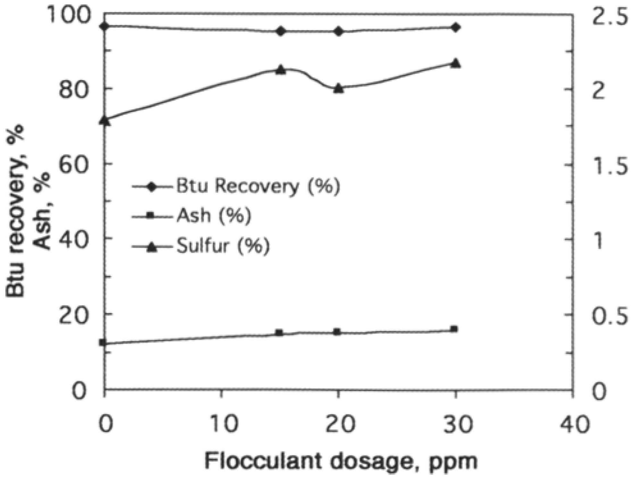

Figure 2 — Effect of anionic flocculant dosage on Btu recovery, ash and sulfur contents of clean coal.

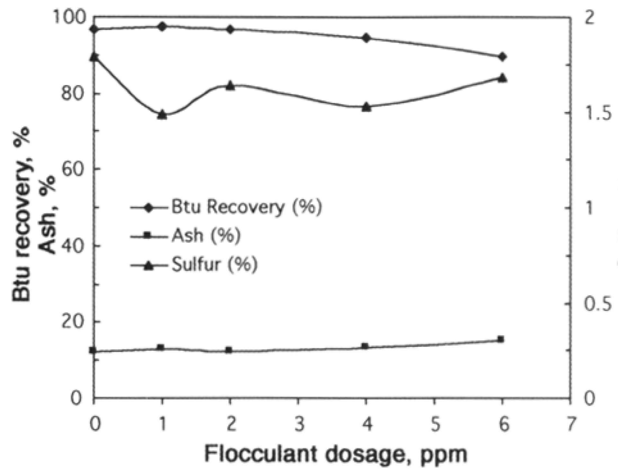

Figure 3 — Effect of nonionic flocculant dosage on Btu recovery, ash and sulfur contents of clean coal.

9.00 corresponds to critical micelle concentration. This may be true, but at high alkaline pH, the ionization of polymer functional group is complete. According to Somasundaran (1991), the polymer must be stretched out, providing a hydrophobic surface coating on the coal surface.

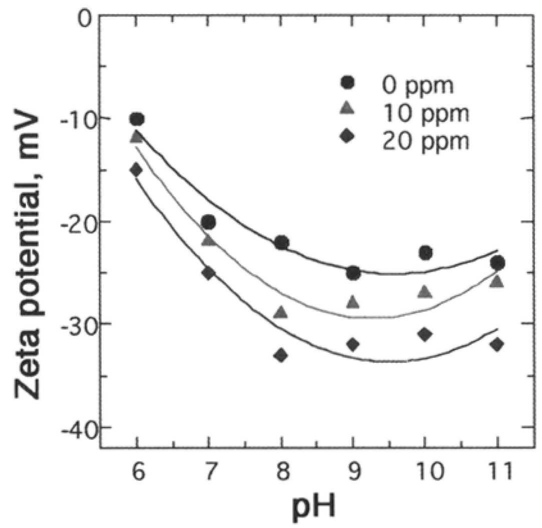

Figure 4 — Zeta potential of coal flocculated with different concentration of anionic flocculent with respect to pH.

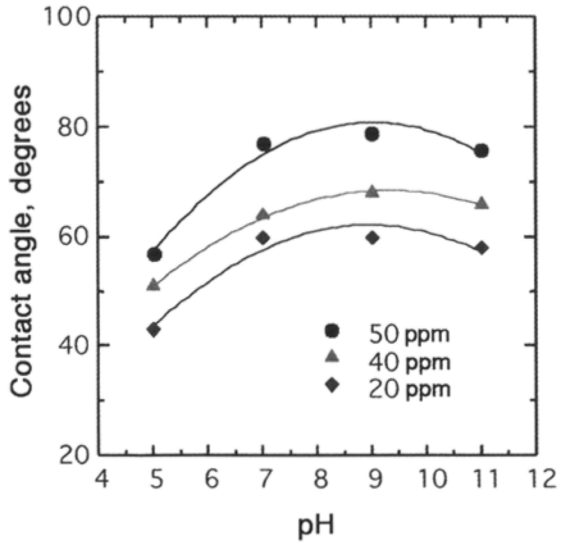

Figure 5 — Contact angle of coal coated with different concentrations of anionic flocculent with respect to pH.

Conclusions

Based on the results obtained in the study, it can be concluded that:

- Baseline flotation data of the fine ground (80% passing 45 μm) Upper Freeport coal showed that by using 250 g/t fuel oil and 250 g/t MIBC, a clean coal with 8% ash at an 80% yield could be obtained.
- Coal flocculated with cationic, nonionic and anionic flocculants responded to froth flotation, providing clean coal containing about 10% to 12% ash at >80% heating value recovery.
- For the anionic flocculant, there is a strong correlation between coal flotation (heating value recovery) and contact angle. Contact angle data shows that adsorption of flocculants increased the hydrophobicity of coal surface.
- Using the anionic flocculant, the zeta potential of the coal reduces in absolute magnitude with increases in flocculant dosage, reaching a maximum around pH 9.0. The contact angle also reached a maximum at pH 9.0. It is speculated that the ionization of polymer along with the stretching of polymer on coal surfaces is responsible for providing a hydrophobic surface.

Acknowledgement

The authors acknowledge the assistance provided by P.T. Brauch and J. Wiseman in conducting some of the experiments. Summer internship support for Brauch was provided by the U.S. Department of Energy.

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