EFFECT OF NEGATIVE AND POSITIVE BIAS ON IMPROVEMENT OF COALS USING COLUMN FLOTATION

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ABSTRACT

Two coals from Copelmi colliery (Brazil) and Cerrejon colliery (Colombia) were floated using negative and positive bias in a 5 cm diameter conventional flotation column. Flotation parameter investigated included air velocity in the range 0.6 to 1.5 cm/s. For all runs, a pulp concentration of 8 % w/w, a commercial frother Aerofroth 65 (AF65) and collector kerosene were used. Results showed that, in general, ash content of floats was lower than that of the parent coals. The lowest ash recovery was obtained using positive bias at the range 3.6-7.8% for the Brazilian coal, whereas 4.9-13.3% for the Colombian coal. The highest mass yield for the Brazilian coal (32.3%) and for the Colombian coal (60.9%) was obtained with a negative bias at an air velocity of 0.6 cm/s.

Key-words: Negative bias. Positive bias. Column flotation. Coal

RESUMEN

Dos carbones de las minas Copelmi (Brasil) y Cerrejon (Colombia) se flotaron en una columna convencional de flotación de 5 cm de diámetro usando bias negativo y positivo. Un parámetro de flotación usado fue la velocidad de aire en el rango 0.6 a 1.5 cm/s. Una concentración de pulpa de 8% p/p, un espumante comercial Aerofroth 65 (AF65) y un colector kerosene se usaron en todas las corridas. Los resultados mostraron que, en general, el contenido de ceniza de los flotados fue menor que el de los carbones originales. La menor recuperación de ceniza se obtuvo usando bias positivo en el rango 3.6-7.8% para el carbón brasilero, mientras que 4.9-13.3% se obtuvo para el carbón Colombiano. El mayor rendimiento con bias negativo a una velocidad de aire de 0.6 cm/s se obtuvo para el carbón brasilero (32.3%) y para el carbón colombiano (60.9%).

Palabras clave: *Bias negativo, Bias positivo, Columna de flotación, Carbón*

1 INTRODUCTION

Brazil and Colombia have the most important proved reserves of coal in South America. Brazil has important reserves of lignite and sub-bituminous coal of 7059 Mt, whereas Colombia has 6434 Mt of anthracites and bituminous coal (BP, 2010). Coal mines in Brazil are located mainly at the South of the country, while in Colombia are situated at the North. Despite Cerrejón mine (Colombian coal) be one of the most important exporter worldwide, it has some beams with high ash concentrations. On the other hand, Copelmi mine (Brazilian coal) presents higher ash concentration than Colombian coal. Both coals, with those characteristics, are not attractive to export or use at thermal process. Therefore, an international cooperation between the Universidad del Valle (Cali-Colombia) and the Universidad Federal do Rio Grande do Sul (Porto Alegre, Brazil) look for to improves their quality through any technology.

Column flotation represents one of the most accepted technologies for upgrading fine coal particles (Kohmuench et. al, 2007, Oh-Hyung et.al, 2014). Bias, defined as the difference between tailing flow and feed flow, plays an important role on recovery and selectivity. In a positive bias (tailings flow is higher than feed flow), wash water flow is added at the top of the column in order to stabilize a deep froth bed and reduces the entrainment recovery of fine gangue (Oteyaka y Soto, 1995). However, excessive positive bias reduces the particle residence-time in the collection zone as well as dilutes the tails stream. By contrast, using a negative bias (tailings flow is lower than feed flow), the froth layer is eliminated, which increase the entrainment of fine particles, deteriorating the concentrate grade (Maldonado et. al, 2008).

Columns working with negative bias have been used for the recovery of coarse sizes such as potash, cooper and fluorite (Soto y Aliaga, 1993; Sampaio, et. al, 2005; Aliaga et.al, 2006). Using negative bias, flotation columns can process high throughput with high pulp concentration for recovering selected coarse mineral particle. It reduces also capital cost due to reduce equipment size, floor space requirements and pulp–froth interface control system, as well as, reduces water and energy consumption and maintenance cost (Hutwelker, 1994).

In this work, Brazilian and Colombian coals were floated in a column flotation using both a negative and a positive bias. The effect of air velocity on yield, organic recovery, ash recovery and water recovery was evaluated.

2 EXPERIMENTAL

Two coal samples from Cerrejon Colliery (North of Colombia) and Copelmi (South of Brasil) were used in this study. Ash content of feed samples from Cerrejón and Copelmi were 25.44% w/w and 52.95 % w/w (dry basis, db) respectively. The coal samples were ground and sieved down to 200 mesh. A 5 cm diameter conventional flotation column of 5 m high and made from acrylic material was used in this study.

2.1 EXPERIMENTS WITH NEGATIVE BIAS

All experiments were performed using a single stage of separation in the column with a pulp concentration of 8 % w/w. For the Colombian coal, a collector (kerosene) concentration of 907 g/ton and frother (Aerofroth-65, AF-65) concentration of 300 g/ton were used, whereas for the Brazilian coal, the collector concentration was 1814 g/ton and frother concentration 600 g/ton.

The runs were carried out using as control variables, the negative bias and air flow. The negative bias was -0.25 cm/s whereas five air velocities (0.6, 0.8, 1.0, 1.2 and 1.5 cm/s) were used. The response variables were yield, organic matter recovery, ash recovery and water recovery in the floats. At all experiments, pH (natural pH) and concentration of frother and collector were constant.

2.2 EXPERIMENTS WITH POSITIVE BIAS

In these runs, it was also used a single stage of separation at the column flotation with a pulp concentration of 8% w/w, and AF-65 and kerosene as flotation reagents. For the Colombian coal, 907g/ton of kerosene and 300g/ton AF-65 were used respectively, whereas for the Brazilian coal, 1814 g/ton of collector and 600g/ton of frother were employed. The feed flow was 0.84 cm/s. Air velocities of 0.6, 0.8, 1.0 and 1.2 cm/s were used for the Cerrejon coal, whereas 0.6, 0.8 and 1.0 cm/s for Copelmi coal. It was noted that for the Brazilian coal, using higher air velocity was not possible to stabilize the interface between the cleaning and collection zones of the column, which was due to the high coalescence of air bubbles and the fluctuation of the interface.

3 RESULTS AND DISCUSSION

3.1 EFFECT OF NEGATIVE BIAS

Figures 1 through 4 illustrate the effect of air rate on the flotation performance at negative bias (-0.25) for both Brazilian and Colombian coals. Figures 1and 2 show the yield and organic recovery as a function of air rate respectively, whereas Figures 3 and 4 illustrate ash recovery and water recovery data respectively. As it is shown in Figures 1 to 4, using Brazilian and Colombian coals, significant differences related to yield, organic recovery, ash recovery and water recovery as a function of air rate are observed.

For the Colombian coal, in general, yield, organic recovery, ash recovery and water recovery decreased with the increasing air rate. However, for Brazilian coal the air rate had no significant effect, revealing that maybe the hydraulic transport predominated on the flotation process.

Figure 1 - Effect of air rate on yield with negative bias

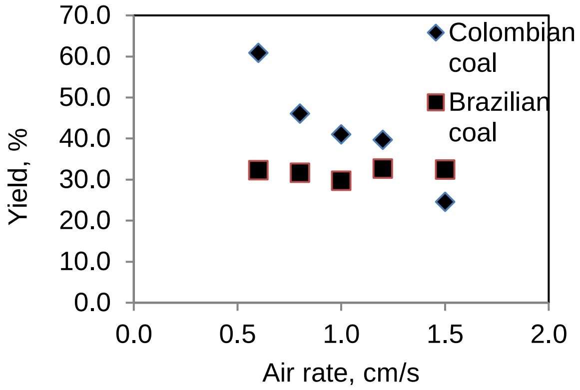
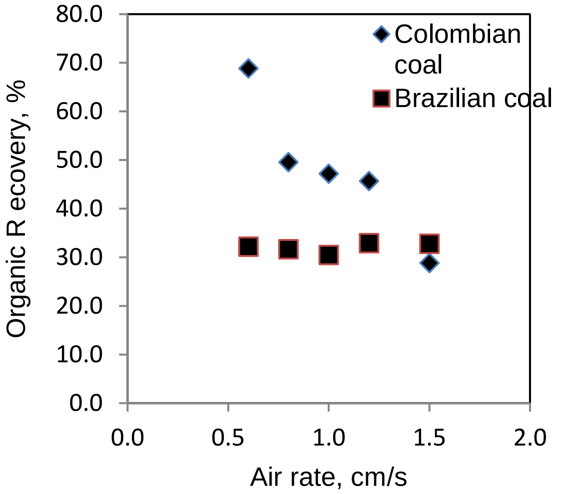


Figure 2 - Effect of air rate on organic recovery with negative bias



For the Colombian coal, the highest yield (60% w/w) and organic recovery (69% w/w) were obtained at the lowest air rate (0.6 cm/s). These findings were consistent with those of Piñeres & Barraza, 2012, who show that for low air flows, bubbles diameter are smaller, increasing surface area of bubble and producing laminar flow conditions. Thus, low air flows increase residence time and the probability of particle-bubble adhesion. Therefore, high yields and organic recoveries were obtained. Hutwelker (1994) reported the same behavior for alumina recovery in a column flotation using negative bias rate and by Sampaio et. al (2005) for copper minerals recovery in column using negative bias. Figure 3 illustrates the effect of air rate on ash recovery, indicating that smallest air rate entails highest ash recovery. In general high yields, as those obtained at low air flows, produce high ash recoveries maybe due to the associated mineral matter that is leaded to the froth.

Figure 3 - Effect of air rate on ash recovery with negative bias

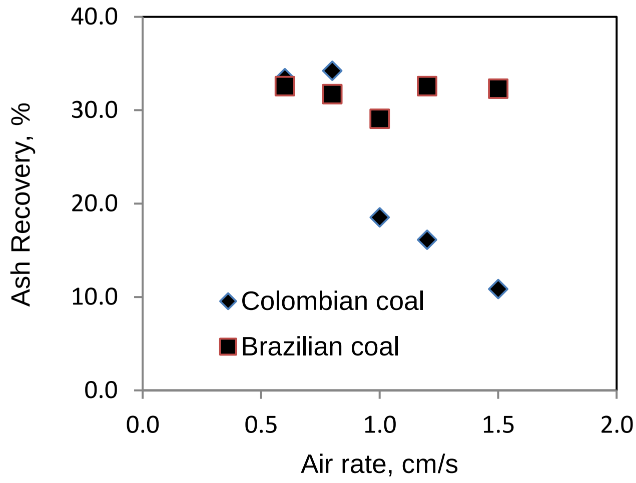


Figure 4 - Effect of air rate on water recovery with negative bias

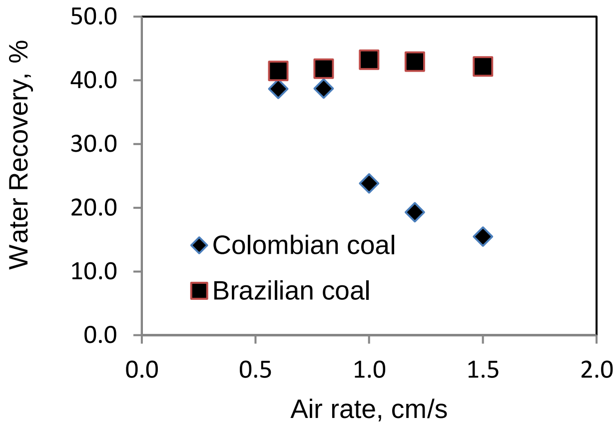


Figure 4 shows that, for the Colombian coal, the water recovery was increased at the lower airflows. At negative bias rate, higher air flow implicates major air content through the control volume of the flotation column. This entails that a smaller water content leave the process for the top of the column because there is more air volume (holdup) moving across the column when the air flow is increased.

The Brazilian coal did not show any significant variations of the parameters and it was not a function of the air rate employed. However, even with those results, it was observed that the mass recovery is very low, with values around 30%. The ash content and organic recovery also showed values around 30%.

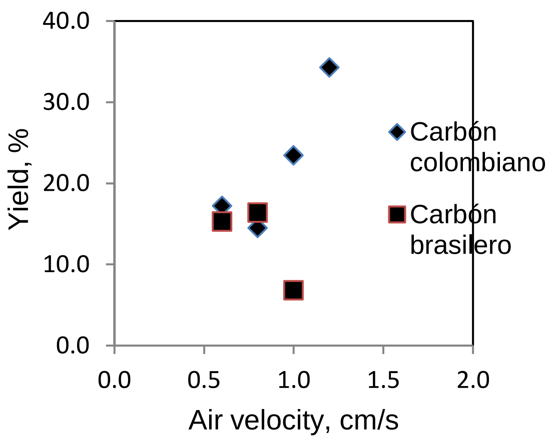
The recovery of water was very high and it was not function of the airflow.

3.2 EFFECT OF POSITIVE BIAS

Figures 5 to 8 show the effect of air velocity on coal flotation using positive bias. Figures 5 and 6 present the mass yield and organic recovery function of air velocity, whereas Figures 7 and 8 show the ash recovery and water recovery respectively figures respectively.

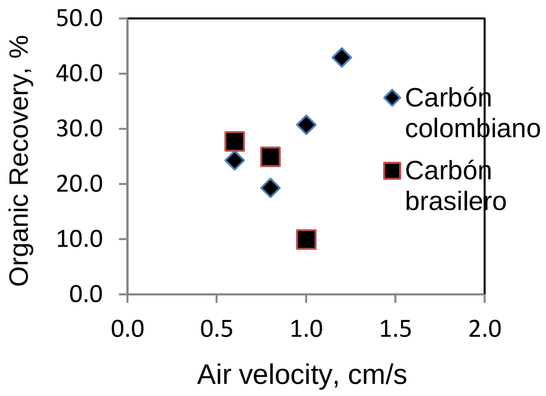
As it is seen in figure 5 and 6, there is a contrary tends of yields and organic recovery for the two coals. Those figures show that, for the Colombian coal, yield and organic recovery increased with increasing air velocity. However, for the Brazilian coal occurs an opposite behavior.

Figure 5. Effect of air velocity on yield using positive bias



For the Colombian coal, the highest yield and organic recovery (about 34 % and 43% respectively) were obtained at a air rate of 1.2 cm/s, whereas for the Brazilian coal, the best results (about 15% and 28%) were reached at a velocity of 0.6 cm/s. Usually, at low air rate, high yield and organic recoveries were produced, which may be caused by the developed laminar flow and by the generated small diameter bubbles. Increasing of surface area of the bubbles, due to its small diameter, increase the probability of particle-bubble adhesion, therefore high yields and organic recoveries were reached.

Figure 6. Effect of air velocity on organic recovery using positive bias



For the Colombian coal flotation under positive bias conditions, high air velocity produces entrainment of pulp, which seems to favor that greater amount of material being pulled through the foam bed. At high air rate, high organic recoveries were obtained, which can be inferred that the organic matter of the Colombian coal is released and floats naturally, therefore the combustible material has an affinity towards the concentrates stream and leaves the process through the top of column.

Figure 7 shows the ash recovery as function of air velocity. In this case, high ash recoveries were also found at the same air velocities used for the yields and organic recovery. It is due to associated mineral matter suffer entrainment towards concentrate stream.

Figure 8 shows that water recovery increased with increasing air velocity for the flotation of the two coals considered in this study. Using positive bias operation, great amount of air bubble produced by the high air rate generated high amount of pulp and water.

Both pulp and water are drawn towards the top of the equipment through the spaces between bubbles. When the equipment has big diameter, those spaces will be higher and more water will move through the foam bed, leaving the column in the concentrates stream.

Figure 7 - Effect of air velocity on ash recovery using positive bias

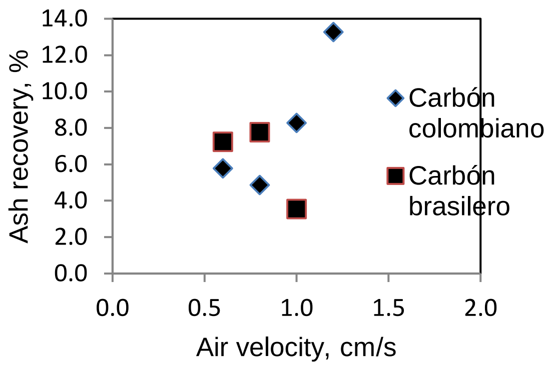
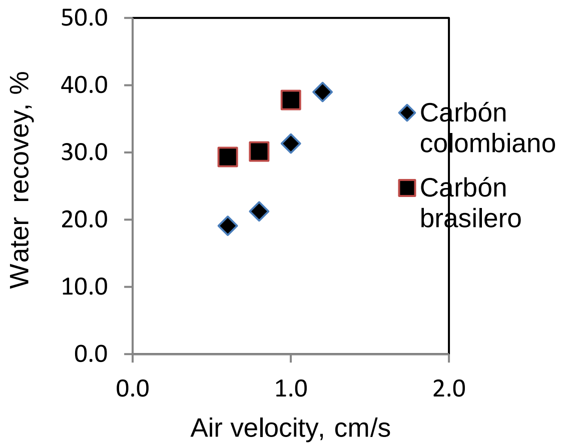


Figure 8 - Effect of air velocity on water recovery using positive bias



4. CONCLUSIONS

Using negative bias, the column flotation showed significant differences in yield, organic recovery, ash and water recovery. In general, yield, organic recovery, ash recovery and water recovery increased with the decreasing air rate for the Colombian coal, but the air rate had no significant effect for Brazilian coal. Yields percentages up to 32.3% for the Brazilian coal and 60.9% for the Colombian coal were obtained. Those yields were obtained at air velocity of 0.6 cm/s. Regarding positive bias, high yield and organic recoveries were produced at low air rate. For the Colombian coal, the highest yield and organic recovery (about 34 % and 43% respectively) were obtained at a rate air of 1.2 cm/s, whereas for the Brazilian coal, The best results (about 15% and 28%) were reached at a rate velocity of 0.6 cm/s. High ash recoveries were also found at the same air velocities used for the yields and organic recovery.

6. ACKNOWLEDGEMENT

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7. REFERENCES

ALIAGA W.; SAMPAIO C.; BRUM I.; FERREIRA K.; BATISTELLA M. Flotation of high-grade fluorite in a short column under negative bias regime. *Minerals Engineering.* 19, 1393–1396. (2006)

BP STATISTICAL REVIEW OF WORLD ENERGY. Available at: http://www.bp.com/statisticalreview. (2010)

KOHMUENCH J.; MANKOSA M.; LUTRELL G. Fine coal cleaning: A review of column flotation options and design considerations. *Designing coal preparation plant of the future*, SME, 97. (2007)

HUTWELKER J. High throughput flotation column process. *United Sates Patent* 537937. (1994).

MALDONADO M., DESBIENS A.; DEL VILLAR R.; CHIRINOS J. On-line bias estimation using conductivity measurements, *Minerals Engineering.* 21, 851–855. (2008).

OH-HYUNG H.; MIN-KYU K.; BYOUNG-GON K.; NIMAL S.: CHUL-HYUN P. Fine coal beneficiation by column flotation. *Fuel Processing Technology.* 126, 49–59. (2014).

OTEYAKA B.; SOTO H. Modelling of negative bias column for coarse particles flotation. *Minerals Engineering*. 8 (1/2), 91-100.(1995).

PIÑERES J.; BARRAZA J. Effect of pH, air velocity and frother concentration on combustible recovery, ash and sulphur rejection using column flotation, *Fuel Processing Technology.* 97, 30–37. (2012)

SAMPAIO C.; ALIAGA W.; VILLANUEVA M., Rougher flotation of copper minerals in columns, Minerals Engineering 18, pp. 731–733. (2005).

SOTO H.; ALIAGA W., Application of column cells to potash flotation in brines, Trans. Inst. Min. Met. Sect. C. 10. (1993).