The application of Baleen Filter microscreening technology at BECSA's South Export Plant

by S. Tshikhudo* and V. Shikwambana*

Synopsis

This paper outlines an investigation into the recovery of saleable fractions of coal from 'as-arising' South Export Plant effluent streams, using Baleen microscreening technology. South Export Plant, a subdivision of BHP Billiton Energy Coal SA (BECSA) Coal Processing, is a two-module plant treating 2000 t/h. The nominally -150 μm coal is untreated and is therefore passed from classifying cyclones to the thickeners for process water recovery. The thickened underflow is pumped into a series of slurry cells for further settling and recovery of supernatant water. The marginal quality, moisture content, and handlebility of this settled material renders it unsuitable for inclusion into saleable products and it is thus stockpiled and trucked to designated pits for disposal.

Over the years, stockpiling and trucking has become an overly expensive exercise. In an effort to recover some of this cost, a task team was assigned to investigate less costly options to process slurry across BECSA plants. Various technologies such as froth flotation, sieve bends, and Reflux Classifier were considered, although the results were generally not beneficial – this could be attributed to weathered/oxidized coal.

A decision was made to pursue an alternative approach by testing the suitability of the new 'Baleen Filter'. The concept is to screen out the higher-grade fraction (+50 μm) as saleable product and reject the finer fractions to the slurry ponds.

The Baleen Filter was found to effectively screen at an acceptable efficiency between 94% and 99.99%, with a very sharp cut-point (d_{50} and *Ep*). The actual yields from the screening results were better than the predicted yields in terms of both mass and energy as predicted from feedstock analysis.

Keywords

Fine coal, coal slurry, upgrading, screening, Baleen Filter, thickener feed.

Introduction

The South Export Plant of BHP Billiton Energy Coal SA (BECSA) is a two-module dense medium separation (DMS) plant designed to process 2200 t/h run-of-mine (ROM) coal with a nominal top size of 50 mm into a range of products for both the domestic and the export markets. Slimes from the plant consist of -150 μm particles, which constitute approximately 6% of the feed to the plant. This is initially dewatered using thickeners and then pumped to slimes dams for temporary storage and drying over a period of 7 months. The slimes are later reclaimed and hauled to designated pits for disposal. The process of slurry reclamation and disposal is cost-intensive, and in an effort to reduce the cost an initiative was undertaken to explore more cost-effective slurry handling techniques.

The quality and handlebility of the settled slurry render it unsuitable to be included in the saleable products in its unprocessed form. Various technologies such as the Baleen Filter, flotation, Reflux Classifier, and sieve bend were considered as techniques for upgrading the slurry to a saleable product. The Baleen Filter technology was considered on the basis of its novelty and feasibility compared to other operations. The idea around the use of the Baleen Filter is to recover material above a specified cut-point based on size that results in a saleable product and rejection of the screen undersize. Following extensive prefeasibility test work conducted on the thickener feed, a 50 μm screen aperture was found most suitable as a starting point for the pilot plant. A 2.78 m^2 pilot plant was therefore erected to process a portion of the feed to the thickeners.

Project objective

The objective of the project was to evaluate the effectiveness and benefits of Baleen Filter technology in upgrading the thickener feed to qualities that will be suitable for either the domestic or the export market. This project was conducted by taking a limited number of samples over a period of time. It was designed to provide an initial view of the operational parameters of the Baleen Filter. In addition, the effectiveness of the screen was also investigated in terms of screening efficiency and sedimentation of the underflow and feed material.

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Baleen pilot plant overview

Figure 1 provides an overview of the Baleen Filter process. The feed is drawn from the thickener feed head box with a 250 mm diameter pipe connected to the Baleen feed box. The pipe is fitted with a manual valve to control feed rate to the Baleen Filter. The feed flows over the screen, which removes -50 μm particles to the underflow and recovers +50 μm particles in bags situated at the discharge end of the screen. Clarified water is used for pressurized sprays to facilitate the screening process by dislodging material from the screen and scraping off the oversize to the discharge. This is connected to a mobile spray rack that is pneumatically controlled and moves up and down the screen continuously. The underflow from the screen reports to the thickener sump, from where it is pumped to the slimes disposal tank. The bags containing the recovered oversize are allowed to dry over time and later shipped to Australia for further binderless coal briquetting testing.

The clarified water added to the sprays should be solids-free to prevent blockages of the sprays, as they are the central part of the Baleen separation process. A water filtration plant accompanies the Baleen Filter to remove all suspended solids, particulates, and scale-inducing constituents from the water prior to feeding to the sprays.

Operating principle

The Baleen Filter or micro-screening technology is based on a 'double-act' of high- or medium-pressure, low-volume sprays, one of which dislodges material caught by the filter media, while the other sweeps it away. As water flows through the filter, particles initially suspended in the water are left behind, but before they are allowed to accumulate, the 'double-act' sprays sweeps away the solids from the filter media into bags. A travelling spray boom self-cleans the static screen. The boom is pneumatically driven from its upper limit to the lower limit (Baleen Filters, 2011).

Experimental procedure

Equipment test

Measurements taken included:

- ➤ Amount of water consumed to aid with screening process (time taken to empty the particulate-free water holding tank)
- ➤ Spray boom cycle time (time taken to move the spray rags from one end to the other, cycles per minute)
- ➤ Flow rate into the Baleen Filter from the 250 mm HDPE pipe (measured with a Doppler flow meter).

Test methodology

The Baleen performance test was done at South Export laboratory according to ISO standard. A flow diagram of the sample preparation and analysis procedure is shown in Figure 4.

Table I

Baleen screen operational parameters

Parameter	OEM specification
Water pump	8 bars
Compressed air output	5 bars
Sprays	3.9 m^3/h
Spray boom	10 cycles/min
Medium flow - spray nozzle (15 bars)	0.0867 m^3/h per/nozzle
Number of bottom sprays	30 sprays
Number of upper sprays	15 sprays
Area of Baleen	3 m^2
Angle of repose	30°
Feed flowrate	50 m^3/h
Feed RD	1.01–1.04
Aperture size	50 μm

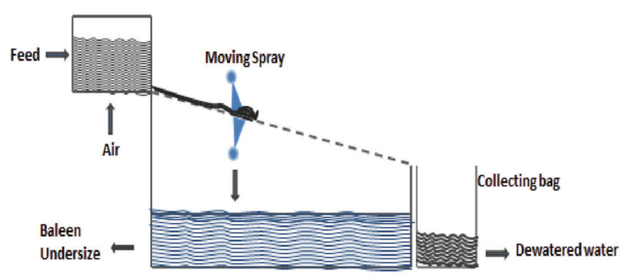

Figure 2—Baleen micro-screen cross-section

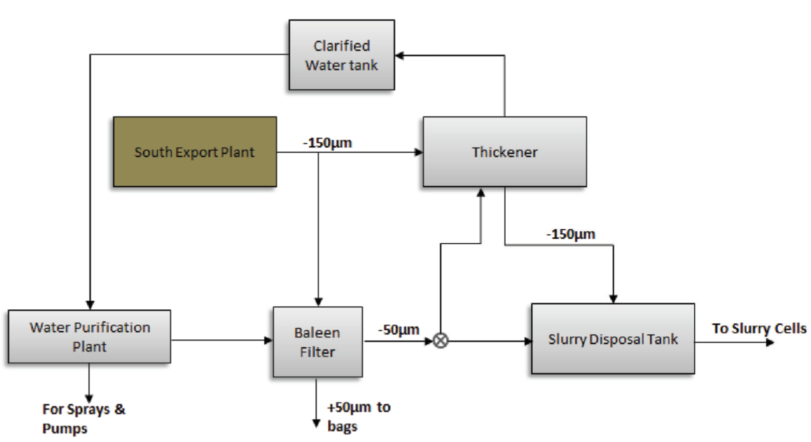

Figure 1—Baleen micro-screen flow diagram

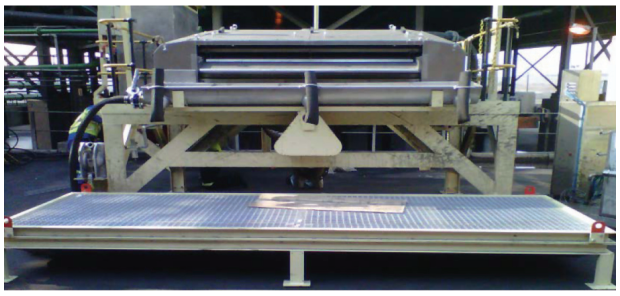

Figure 3—Baleen micro-screen

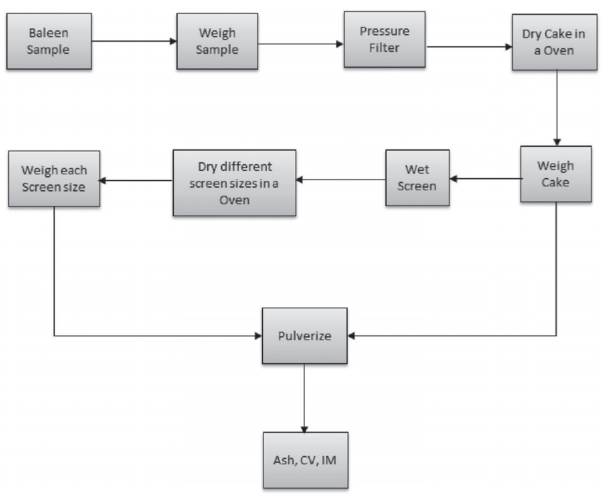

Figure 4—Sample preparation and analysis

Samples were taken from the Baleen feed, undersize, and oversize at 2-minute intervals for an hour over a number of days and composited. Samples were weighed, pressure filtered, dried in a 40°C oven, and again weighed. Filter cake was wet-screened on a test sieve at 300 μm, 212 μm, 150 μm, 106 μm, 63 μm, and 45 μm apertures using a vibrator sieve shaker, and also hand screened. The samples for quality analysis were then air-dried.

Settling test

The percentage solids samples were prepared from the thickener feed and Baleen undersize. Magna flocculant 919 with strength of 0.05% m/m was dosed into a 500 ml or 1000 ml slurry measuring cylinder. The required amount of flocculant was added as a split dose, by adding half of the amount and inverting the cylinder three times; the remaining flocculant was then added and the cylinder inverted twice then placed on a workbench. Settling rate was determined by measuring the time taken for the slurry to settle in the measuring cylinder. Optimal flocculant consumption was determined from the clarity as measured using a Ciba clarity wedge. Compaction or dewatering rates were determined for periods of 2 h, 8 h, and 24 h.

Results and discussion

Table II shows that the Baleen Filter using a 50 μm screen cloth upgraded the fines material from an ash content of 36.6% to an oversize material with an ash content of 21.09%.

Partition coefficient

The ash balance calculation (Equation [1]) was used to determine the mass split between the Baleen screen oversize and undersize material.

$$Yield = \left(\frac{x_{A(US)} - x_{A(F)}}{x_{A(US)} - x_{A(OS)}}\right) \times 100 \qquad [1]$$

where

$x_A(US)$ = fractional ash composition in the undersize
$x_A(F)$ = fractional ash composition in the feed
$x_A(OS)$ = fractional ash composition in the oversize

$$= \left(\frac{0.5983 - 0.3664}{0.5983 - 0.2109}\right) \times 100$$

$$= 59.96\% \text{ (Oversize material)}$$

The size analysis of the screen undersize and oversize is shown in Table III.

Table II

Screen product qualities

Test	Feed (% ash)	Oversize (% ash)	Undersize (% ash)
1	33.08	22.9	59.8
2	35.65	18.41	66.2
3	33.44	21.97	38.42
4	40.6	20.4	59.9
Average	**36.64**	**21.09**	**59.8**
STDEV	**3.46**	**1.97**	**3.66**

Table III

Sizing data for the Baleen screen oversize and undersize particles

Aperture size, μm	Mean size, μm	Oversize		Undersize		Calculated feed	Partition coefficient
		% Mass	Mass in sample (g)	% Mass	Mass in sample (g)		
+300	387.3	3.3	2.0	0.0	0.02	2.0	0.99
+212	252.2	7.4	4.4	0.0	0.01	4.5	1.00
+150	178.3	14.8	8.9	0.1	0.05	8.9	0.99
+106	126.1	26.3	15.8	0.3	0.14	15.9	0.99
+63	81.7	23.6	14.1	0.6	0.23	14.4	0.98
+45	53	14.1	8.5	0.7	0.27	8.7	0.97
-45	33.5	10.5	6.3	98.2	39.33	45.6	0.14
		100	59.96	100.0	40.04		

The partition coefficient may now be plotted on semi-log paper as shown in Figure 5.

It can be seen that:

The separation size

$$d_{50} = 42\mu\text{m (tromp cut)},$$

$$d_{75} = 47.9\mu\text{m, and } d_{25} = 36.1\mu\text{m}$$

The efficiency,

$$EP = \left(\frac{d_{74} - d_{25}}{2}\right) = \left(\frac{0.0479\text{ mm} - 0.0361\text{ mm}}{2}\right) = 0.0059 \quad [2]$$

The imperfection

$$I = \frac{E_P}{d_{50}} = \left(\frac{d_{75} - d_{25}}{2d_{50}}\right) = 0.140 \quad [3]$$

The Baleen Filter is fitted with a 50 μm aperture size screen cloth, and it was found that the screen is operating at a cut size of 42 μm.

Misplaced material

Figure 6 shows the average size distribution of the feed, undersize, and oversize. It can be seen that at a d_{50} of 42 μm, the misplaced particles to the undersize and oversize are 1.9% and 8.1% respectively.

Overall efficiency

The mass balance around the screen is derived in terms of feed, undersize, and oversize:

$$m_{S(F)} = m_{S(O)} + m_{S(U)} \quad [4]$$

where:
$m_{S(F)}$ = mass of solids in the feed

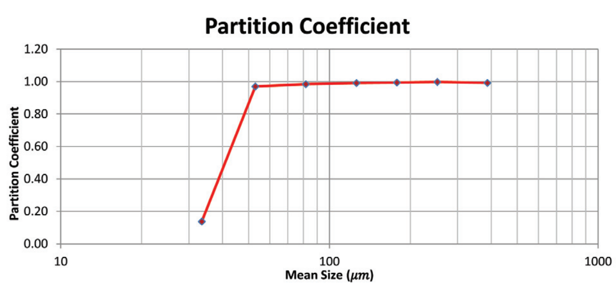

Figure 5—Tromp curve of Baleen screen data from Table III

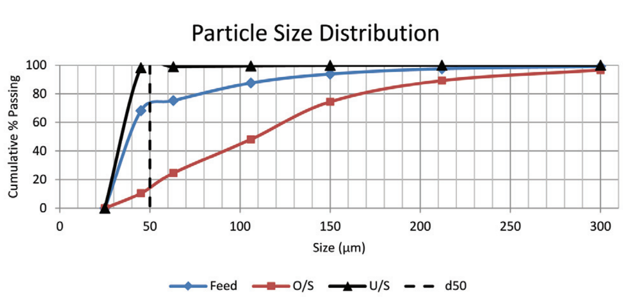

Figure 6—Particle size distribution of feed, oversize, and undersize

$m_{S(O)}$ = mass of solids in the oversize
$m_{S(U)}$ = mass of solids in the underflow

The composition of the undersize particles in the feed, oversize, and undersize streams is given by:

$$m_{S(F)} \times x_{U(F)} = m_{S(O)} \times x_{U(O)} + m_{S(U)} \times x_{U(U)} \quad [5]$$

where:
$x_{U(F)}$ = fraction of undersize in the feed
$x_{U(O)}$ = fraction of undersize in the oversize
$x_{U(U)}$ = fraction of undersize in the undersize

Substituting Equation [4] into Equation [5]:

$$\therefore \frac{m_{S(U)}}{m_{S(F)}} = \frac{x_{U(O)} - x_{U(F)}}{x_{U(O)} - x_{U(U)}} \quad [6]$$

'Osborne considered the efficiency of a square aperture screen as the ratio of the amount that actually passes through the screen to the amount that should pass through the screen' (Gupta and Yan, 2006). The screen efficiency (Table IV) is determined as follows:

$$E = \left(\frac{m_{S(U)}}{m_{S(F)} x_{U(F)}}\right) \times 100 \quad [7]$$

Substituting Equation [6] into Equation [7]:

$$\therefore E = \frac{100}{x_{U(F)}}\left(\frac{x_{U(O)} - x_{U(F)}}{x_{U(O)} - x_{U(U)}}\right) \quad [8]$$

$$\therefore E = \frac{100}{0.7015}\left(\frac{0.1438 - 0.7015}{0.1438 - 0.9840}\right)$$

$$\therefore E = 94.62\%$$

Feed particle size distribution

The project is focused on the recovery of fines material using particle size as the selection criterion. From Table V it can be extrapolated or interpolated that fines material at an ash content of 28% can be recovered at a cut size of 35.75 μm at an oversize yield of 63.34%. Alternatively, an ash content of 20 % can be achieved at a screen cut size of 49.5 μm at an oversize yield of 30.03%. However, the partition coefficient of the oversize and undersize shows that the screen was operating at a cut size of 41.6 μm (Figure 5).

The effect of the Baleen screen on thickener operation

One of the primary determinants of settling of material in a thickener is the open area. Installing the Baleen Filter results in a reduction of the solids flow rate to the thickener

Table IV

Summary of Baleen efficiency

Test	Efficiency	d_{50}	Actual yield
1	90.43	40.15	72.41
2	95.29	42.09	63.93
3	102.65	47.00	30.27
4	93.97	43.46	48.88
Average	95.59	43.17	53.87

Table V

Baleen screen feed particle size distribution

Aperture size (μm)	Mass fraction (g)	% mass	Cum. % mass	% ash	Cum. % ash
300	8.5	0.9	0.9	9.1	9.1
212	15.6	1.6	2.5	10.2	9.8
150	35.1	3.7	6.2	13.4	11.9
106	59.7	6.2	12.4	16.0	13.9
63	117.6	12.3	24.7	22.6	18.2
45	67.8	7.1	31.8	29.0	20.6
-45	651.8	68.2	100.0	44.1	36.6
Total	956.1	100.0			

(measured in tons per hour) of 59.96%, which is likely to enhance the performance of the current thickeners due to the increase in the open area available for settling.

Figure 7 and 8 show the results of settling tests on a number of samples taken from the thickener feed and the Baleen Filter undersize material. The percentage solids content of the samples was 2.51%, and the tests were carried out at a flocculant dosage of 30 g/t.

It can be seen that the settling rates of the thickener feed vary from sample to sample, whereas more consistent results were obtained from the Baleen Filter undersize material. However the thickener feed material settles at a faster rate than the Baleen Filter undersize.

Although the results indicate that the installation of the Baleen Filter might have an adverse impact on the rate of settling of the solids, it is important to note that the total mass of solids sent to the thickener would be reduced by 59.96%, and the increased open area thus created in the thickener would aid the settling process.

Dewatering rate

Figure 9 clearly shows that the feed reached its maximum after 4 hours, while the Baleen undersize size has not reached stability after 24 hours. It is expected that the -150 μm fraction has greater percentange of pores than -50 μm slurry. Currently a 7-month sedimentation period is required to dewater the thickener underflow. The impact of the reduction in the amount of solids in the slurry ponds by 59.96%, and the removal of the +50 μm fractions from these solids will need to be investigated further.

Conclusion

It can be concluded that the Baleen Filter is capable of upgrading the thickener feed material for the recovery of higher quality fine material based on size, despite the limited sample data used in this trial. The current trials, which are continuing for approximately 5 months, support this conclusion. The Baleen Filter is capable of treating micro-particles at a screening efficiency of 95.59%. The installed pilot Baleen Filter screen yielded efficiencies similar to larger aperture commercial screens. The installation of the Baleen screen will reduce the amount of solids in the thickener by 59.96%, which could have a positive impact on the operation of the thickeners, particularly when treating Seam 4 material, (4 seam contains a high amount of weathered coal which give rise to a high volume of fines) undersize material. The results clearly show that there will be a reduction in the amount of solids feeding the slurry cells. The overall impact of the removal of the +50 um fraction needs to be explored further.

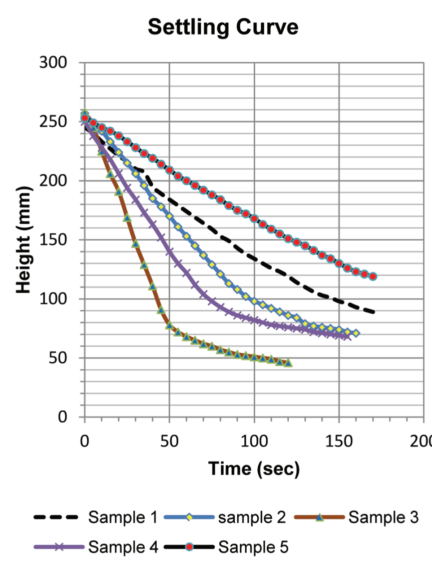

Figure 7—Thickener feed settling results

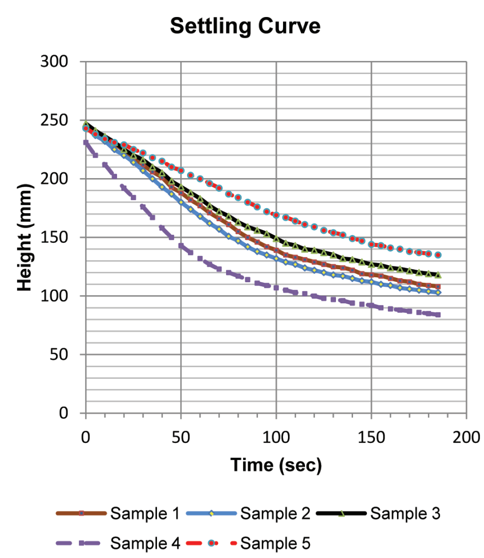

Figure 8—Baleen screen undersize settling results

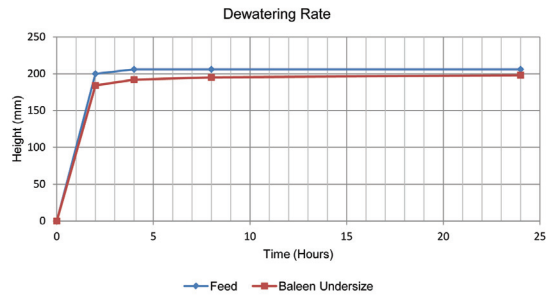

Figure 9—Dewatering rate

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