Gekko IPJ Coal Separator Value Addition in Coal Preparation

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ABSTRACT: The Gekko IPJ Coal Separator (IPJ) is a mature technology that has not previously been applied to the coal industry. It efficiently processes a wide range (60 mesh to 1 ¼ inch or 0.25 to 32 mm) of particle sizes. The IPJ can efficiently process size fractions that include the smaller of those conventionally processed by dense medium cyclones (eg 6 x 0.5mm) and all of those typically processed by spirals or teetered bed separators (2 x 0.125mm). It therefore has potentially important applications that include:

- Enable higher plant throughputs at minimal costs by increasing desliming apertures to 6mm (1/4inch) or higher
- Scavenging misplaced coal in flotation tails
- Reprocessing co-disposed areas at the disposal site prior to pumping to plant for flotation
- Low cost but efficient processing of up to 32mm (1 ¼ inches) particles for, eg, direct power station feed
- De-stoning.

Pilot scale and preliminary plant test results are reported that include the effects of important operating variables.

INTRODUCTION

There is a growing trend for the installation of mid-sized (1.4 x 0.25mm) circuits as they are an effective means of achieving remarkable capital efficiency with respect to new and upgraded plant capacities (Booth and Mills, 2007; Mills and Harmsworth, 2007). The capital efficiencies are achieved by the increased throughputs enabled by simply increasing screen apertures from, for example 0.5mm to 2mm. Material that was previously processed by, for example, dense medium cyclones in the 2 x 0.5mm size range can now be processed in other machines eg spirals (1.5mm top size), teetered bed separators (Drummond et al., 2002) and Reflux Classifiers (Galvin et al., 2004). As these devices handle material down to around 0.125mm, less material is either discarded or treated by flotation.

There are likely to be efficiency benefits achieved in some cases due to reducing the cut point size drift that commonly occurs in dense medium cyclones. In addition, its potential to process coarse as well as mid-sized coal could provide a means to allow larger diameter dense medium cyclones to be installed as the limitation of the breakaway size (Bosman, J., 1998; Bosman, J.E. and Engelbrecht J.A., 1997) may be circumvented.

Additionally, flotation circuits would not be required to process the more troublesome coarser (for example, 0.5 – 0.3mm) particles, thereby increasing overall coal recovery.

The obvious next step of increasing screen aperture to higher levels would likely provide commensurate capital efficiency improvements. However, this has not yet occurred, primarily due to the absence of proven single stage technology to efficiently process the intermediate size material.

The Gekko IPJ Coal Separator offers the potential to provide an industrial solution to this problem as it has been proven in the metalliferous industry and can readily be adapted to coal applications. A structured investigation into the applicability of the Gekko IPJ Coal Separator (IPJ) was therefore undertaken and is not yet complete.

DESCRIPTION OF GEKKO IPJ COAL SEPARATOR

The Gekko IPJ Coal Separator (IPJ) (see Figure 1) is a compact, low cost continuous process that requires minimal infrastructure or logistical support. It is characterised by low capital and operating costs, low power requirements and low water requirements.

The unit was originally developed by Gekko Systems in Ballarat (Victoria, Australia) to beneficiate hard rock minerals. The first unit was sold in 1996 and over the following 10 year period there have been over 100 installations worldwide. The current installation list includes 19 different countries and 8 different minerals, including diamonds, gold, tantalum, tin, copper, manganese, cobalt and garnet.

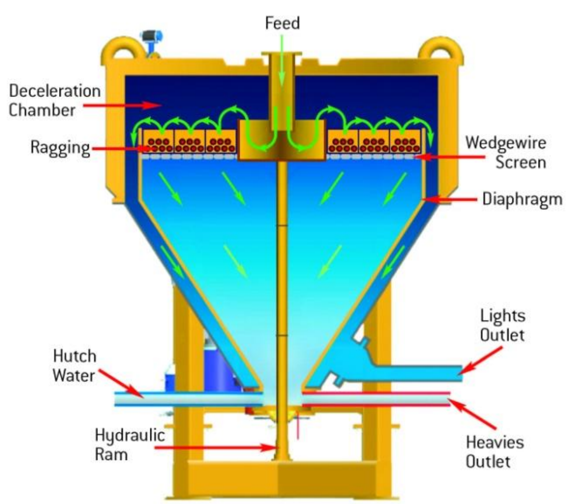
As indicated on Figure 1, the larger models are capable of processing material with a 30mm top size. The unit is fully encapsulated, pressurised, and combines a circular bed with a moveable sieve action. The encapsulation allows the Gekko IPJ Coal Separator to be completely filled with slurry and water. As a result, slurry velocity is slowed and water surface tension effects eliminated improving beneficiation potential for the finer sizes.

Classic jigging units characteristically dilate the particle bed by an upward pulse of water, through a screen, caused by the movement of a remote piston (Wills, 1997). However, the Gekko IPJ Coal Separator moves the screen up and down in a cyclic manner by means of a hydraulically powered servo that is mechanically linked to the screen.

The result is a saw tooth pulse with linear displacements. This effectively creates the classic jigging effect, but also allows for better control of both the bed dilation stroke (downward screen movement) and the settling stroke (upward screen movement). This is unlike the case of a conventional jig where the settlement stroke is dictated by the settling velocity of the feed charge. In addition to this improved control, hutch water feed, which results in an independent variable upwards flow of water, can be used to further improve classification.

Separation is based on relative density as well as particle size and shape. High specific gravity particles are drawn into the hutch during the suction stroke of the bed and are continuously discharged. The lighter material is discharged over the tailboard to the outer cone. Both heavy and light material is discharged under pressure.

The Gekko IPJ Coal Separator has the potential in the Coal Industry to operate more efficiently than teetered bed separators/spirals/reflux classifiers due to the more controllable jigging. In addition, its potential



SPECIFICATIONS

Model	600	1500	2400
Max.Capacity (tph)	2	50	100
Max. Feed Size (mm)	6	30	30
Conc. (tph solids)	0.03 - 0.6	0.3 - 10	1 - 20
Installed Power (kW)	1.5	1.5	2.2
Max. Op. Pressure (kPa)	180	200	200
Hutch Water (l/s)	0.1 - 0.5	2 - 10	6 - 15
Dry Weight (kg) approx.	200	1900	3800

Note: The manufacturer reserves the right to change design specifications without notification at any time.

Figure 1. Schematic representation of Gekko IPJ Coal Separator

to process coarse as well as mid-sized coal could provide a means to allow larger diameter dense medium cyclones to be installed as the limitation of the breakaway size may be circumvented.

There are obvious cost (low capital and operating) and environmental (low water requirements) benefits of the Gekko IPJ Coal Separator technology. It is considered that it may be a viable alternative to some existing coal preparation plant equipment. However, appropriate performance data on coal is not currently available, and this project was designed to provide this data. Specifically, this project focused on particles with a 6mm (1/4 inch) top size.

DETAILS OF PILOT GEKKO IPJ COAL SEPARATOR UNIT USED

The pilot scale Gekko IPJ Coal Separator (Anon, 2002) used was a single hutch, circular jig with moveable screen in which feed enters into the centrally located distributor, where the velocity reduces as the slurry radiates across the circular bed, Figure 2.

As shown on Figure 2, the bed comprises a wedge wire screen and ragging. The ragging consisted of uniformly sized spherical particles (16mm diameter) all with the same relative density (1.6 to 1.8). The ragging particles were larger than the wedge wire screen apertures and formed a bed of around 3 – 4 particles deep. In the static case, it is the packing of the ragging that prevents the coal substrate particles from falling directly through the wedge wire screen and to rejects (heavies). In the dynamic (pulsed with hutch water) situation, the ragging particles also pulse and interact with the pulsing coal particles. The ragging particles also help prevent plugging and pegging in the wedge wire screen.

The screen pulses in a vertical plane with a saw tooth action. Particle segregation was promoted as the jig downward motion was faster than the settling velocity of the feed solids and ragging particles.

The entire unit was encapsulated such that the screen was fully submersed while pulsing. The encapsulation means that the unit operated under pressure (up to 200kPa), and that air must be bled from the unit periodically. It also ensured that there were no air/slurry interfaces interfering with the process.

Hutch water was added and, when combined with the slurry, created a semi-static column of diluted slurry through which the bed pulsed.

The down stroke of the pulse allowed a jigging-type separation to occur, based on differences in solids relative density, size and shape. The upstroke produced suction which caused the heavier sinks material to be drawn down through the ragging into the hutch, and continuously discharged through the tails outlet. The lighter product material was discharged in the concentrate discharge area where it exited under pressure.

Due to the relatively high amount of floats material, the standard Gekko IPJ Coal Separator was modified by Gekko Systems specifically for this project such that there were two floats outlet pipes. In order to maintain the pressure in the separator, both the product and reject pipes were elevated so as to provide a barometric head. In practical terms, this created difficulties with blockages. This problem was overcome for the modular scale site-based test work by using blind cyclones (orifices) on the outlet lines in which the

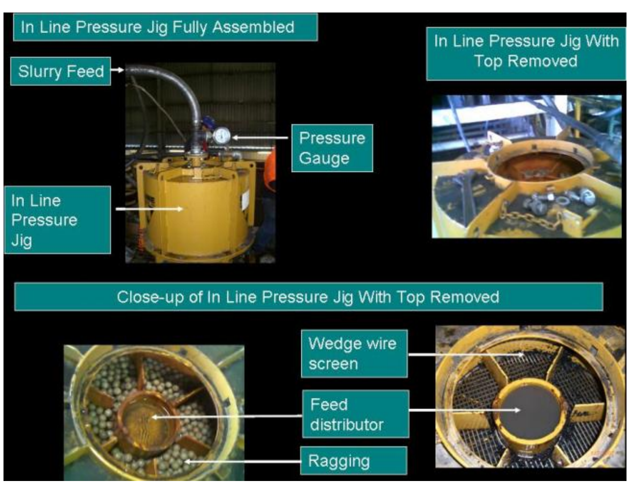


Figure 2. Gekko IPJ Coal Separator feed inlet detail

swirling actions creates the necessary back-pressure. In larger Gekko IPJ Coal Separator units, process controlled pinch valves are used to maintain pressure and flow in the sinks and floats lines.

The unit was fitted with a relatively complex set of actuators and sensors that are part of a PID control system. In simplified terms, the parameters controlled are:

- Stroke amplitude
- Stoke frequency
- Stroke shape.

Whilst it was initially considered that these parameters could be varied independently, there was considerable interaction between the stroke amplitude and stroke frequency parameters such that high settings of both could not be achieved simultaneously. In addition, ball valves and magnetic flow meters on each of the hutch water and tailings flows allowed these parameters to be adjusted manually and independently.

The IPJ 600 unit with a throughput rating of around 1tph was used for the pilot scales tests.

DETAILS OF MODULAR GEKKO IPJ COAL SEPARATOR UNIT USED

An IPJ 1000 skid-mounted modular unit was used for site-based test work with a nominal throughput of around 5 tph. Figure 3 shows a photo of the skid mounted modular unit tested. The IPJ rig was feed continuously with 6mm (1/4 inch) x 0 raw coal from a Hunter Valley coal preparation plant.

RESULTS SUMMARY OF PILOT SCALE (1TPH) GEKKO IPJ COAL SEPARATOR UNIT USED

A full discussion of the pilot scale test results has been reported elsewhere (Vince et al., 2007). Each test condition is shown in Table 1 in which HV denotes a Hunter Valley coal and BB denotes a Bowen Basin coal.

Hunter Valley Partition Coefficient Curves

These are shown in Figure 4, which indicates that the separation of the 6 x 2mm particles was significantly sharper than for the 2 x 0.5mmWW particles. The separations for the 2 x 0.25mm particles was the least sharp with significant high density tails, indicating significant amounts of reject reporting to product. The low density tail was not significant. Table 2 summarises the D_{50} and Ep Values. For the 6 x 2mm particles, Ep values are higher than those expected in a dense medium cyclone, but for the 2 x 0.5mmWW and 2 x 0.25mm particles, the Ep values are similar to those expected of a spirals operation.

Bowen Basin Partition Coefficient Curves

These are shown in Figure 5 which indicates that, except for Test 25, the separation of the 6 x 2mm particles was significantly sharper than for the 2 x 0.5mmWW particles. The separations for the 2 x 0.25mm particles

Figure 3. Skid mounted 10 tph Gekko IPJ Coal Separator on site

Table 1. Test conditions for partition coefficient determinations

Test	Coal	Size (mm)	Ragging RD	Hutch (l/s)	Reject (l/s)	Pulse (cyc/min)	Stroke (mm)	Dry Feed (tph)	Feed % Solids
1	HV	6x0.5WW	1.6	5.1	2.7	76	10	1.03	6.1
6	HV	6x0.5WW	1.6	5	3.8	62	10	1.2	7.0
16	BB	6x0.5WW	1.6	5	2.5	62	10	0.75	4.5
20	BB	6x0.5WW	1.8	6	2.92	61	10	0.73	4.4
21	HV	6x0.25	1.6	5	3.4	76	10	1.12	6.7
22	HV	6x0.25	1.6	5	3.4	62	10	1.10	6.6
24	BB	6x0.25	1.6	5.1	3.4	62	10	0.92	5.6
25	BB	6x0.25	1.8	6.1	3.6	61	10	2.41	22.4

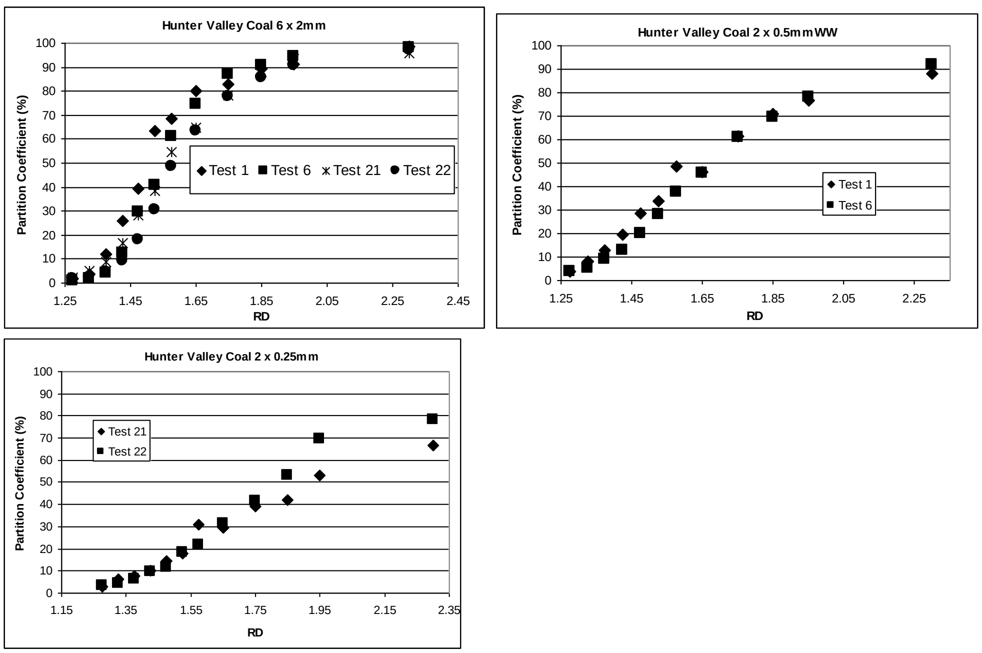


Figure 4. Hunter Valley Partition Coefficient Curves

Table 2. Hunter Valley D_{50} and Ep values

Test	6 x 2mm		2 x 0.5mmWW		2 x 0.25mm	
	D_{50}	Ep	D_{50}	Ep	D_{50}	Ep
1	1.50	0.088	1.58	0.195		
6	1.54	0.105	1.66	0.180		
21	1.55	0.129			1.94	-
22	1.55	0.129			1.80	0.282

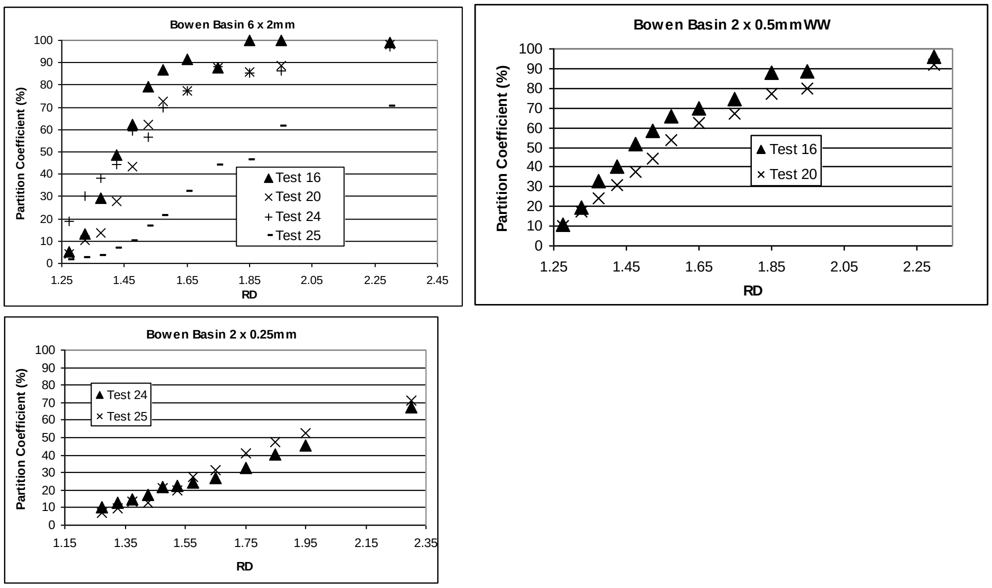


Figure 5. Bowen Basin Partition Coefficient Curves

were the least sharp with significant high density tails, indicating significant amounts of reject reporting to product. The low density tail was not marked.

The feed rate used for Test 25 was very high (2.4tph) and the unit was considered to be overloaded. Table 3 summarises the D_{50} and Ep Values. For the 6 x 2mm particles, Ep values are higher than those expected in a dense medium cyclone, but for the 2 x 0.5mmWW and 2 x 0.25mm particles, the Ep values are similar to those expected of a spirals operation

Operating Points

The above discussion has examined the separating characteristics in terms of partition coefficient curves. An alternative way is to look at how close the actual separation was to perfect separation, as estimated by the washability curve.

Hunter Valley Coal

For these tests, the data shown in Figures 6 – 8 indicates that the operating points were very close to the washability curves.

Table 3. Bowen Basin D50 and Ep values

Test	**6 x 2mm**		**2 x 0.5mmWW**		**2 x 0.25mm**	
	D_{50}	**Ep**	**D_{50}**	**Ep**	**D_{50}**	**Ep**
16	1.43	0.075	1.475	0.200		
20	1.49	0.100	1.550	0.213		
24	1.50	0.150			2.00	-

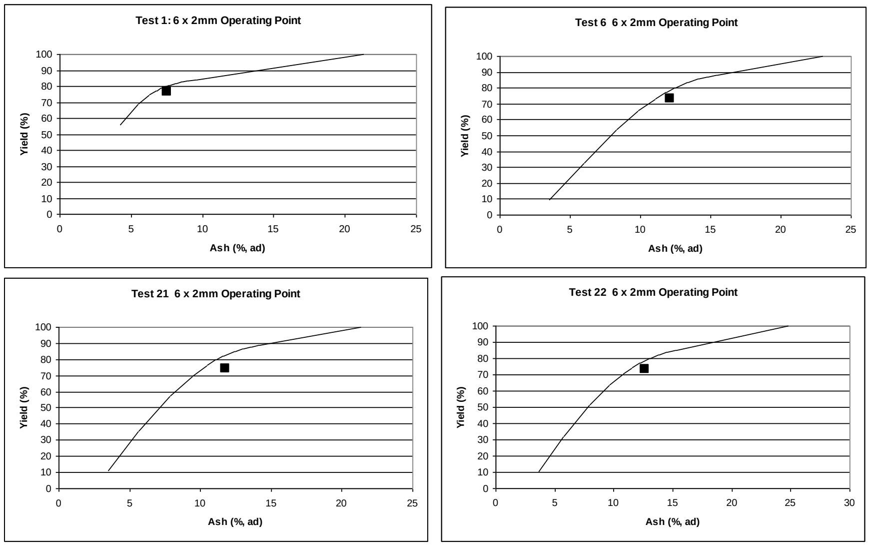


Figure 6 Hunter Valley 6 x 2mm operating points

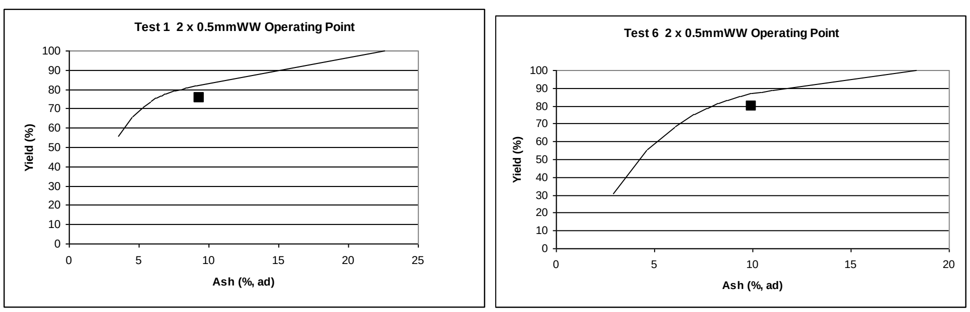


Figure 7 Hunter Valley 2 x 0.5mmWW operating points

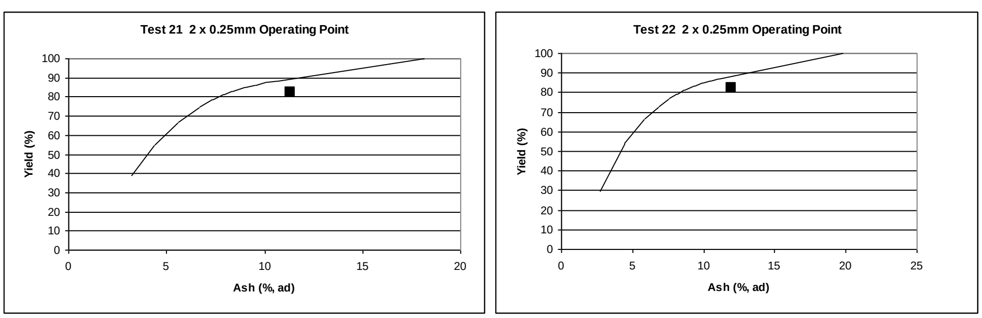


Figure 8 Hunter Valley 2 x 0.25mm operating points

Bowen Basin Coal

For these tests, the data shown in Figures 9 – 1 indicates that the operating points were close to the washability curves. The exception was Test 24.

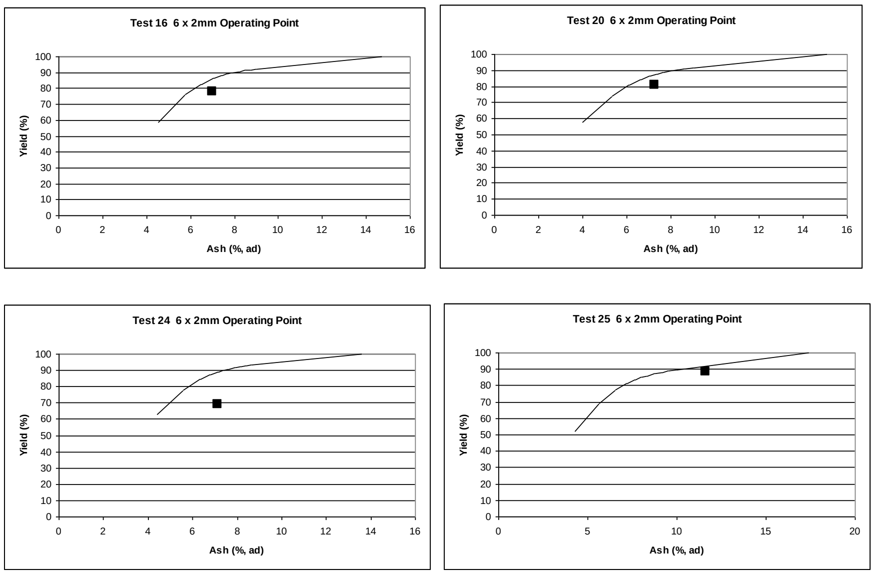


Figure 9 Bowen Basin 6 x 2mm operating points

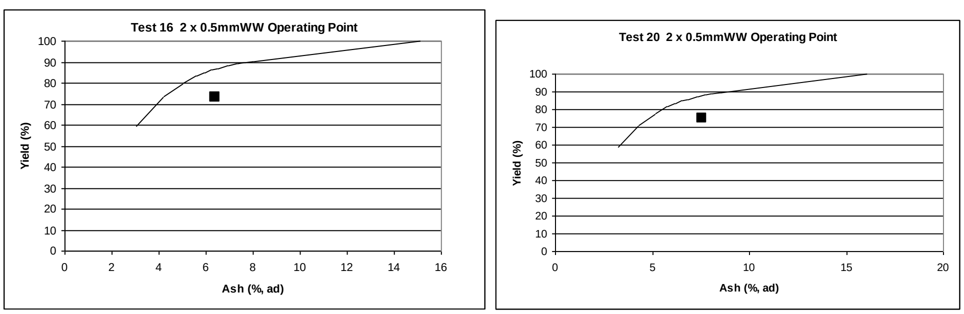


Figure 10 Bowen Basin 2 x 0.5mmWW operating points

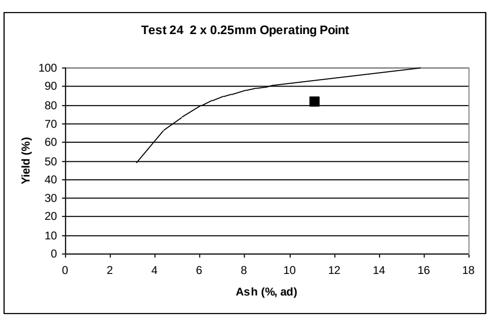


Figure 11 Bowen Basin 2 x 0.25mm operating point

PRELIMINARY FINDINGS FROM 10 TPH GEKKO IPJ COAL SEPARATOR TEST

At the time of writing this paper plant scale tests were underway and so only preliminary results can be reported. As this is a poster paper, it is hoped that more detailed results would be available at the conference presentation. Figure 12 shows partition coefficient curves for 5 tph feed rates at low and high cut points. These indicate that good separations were achieved at D_{50}'s of around 1.68 and 1.40.

MAIN FINDINGS AND CONCLUSIONS

The Gekko IPJ Coal Separator was able to process coal from the Hunter Valley and Bowen Basin regions of Australia with partition coefficient curves that were similar to those expected of spirals units, but with a much broader range of cut points (1.43 – 2.00) and particle size (6 x 0.25mm). It is expected that 30mm top size particles could be processed efficiently.

The Gekko IPJ Coal Separator can add significant value to the coal preparation industry by a combination of significantly higher throughputs from existing plant circuitry and efficiency increases by increasing the bottom size passed to dense medium cyclone circuits.

The unit was evaluated using the ACIRL Maitland pilot plant facility and site-based test work with volumetric feed rates around 16-17m^3/hr and % solids typically around 5%, but ranging up to 22%. The size fraction tested was 6 x 0.5mmWW with a limited number of tests undertaken with 6 x 0.25mm solids. The top size limitation was due to pilot scale solids handling limitations. With minor alternations, a larger sized unit could handle up to 30mm.

The pilot scale unit was able to achieve spiral-like separation efficiencies over a very wide range of D_{50} cut points:

- D_{50}: 1.43 -1.55, Ep: 0.075 - 0.150 for 6 x 2mm particles.
- D_{50}: 1.48 - 1.66, Ep: 0.180 - 0.213 for 2 x 0.5mmWW particles
- D_{50}: 1.80 - 2.00, Ep: 0.282 for 2 x 0.25mm particles.

A very limited one at a time parametric study of feed rate, ragging RD, pulse frequency and stroke length was undertaken to achieve the results reported. However, it is unlikely that optimum operating conditions have been identified by this preliminary investigation.

It is considered testament to the robustness of the design of the Gekko IPJ Coal Separator that such excellent performance was achieved from an obviously un-optimised unit. The unique design feature that led to the good performance was the moving (jigging) of a fully submersed bed of particles on a screen support within a continuum of water. This allowed excellent control of both the dilation (downward screen movement) and the settling stroke (upward screen movement) jigging process, which is unlike a conventional hydraulic jig where settlement is controlled by the settling velocities of the raw feed solids. This is a major improvement to jig design and has the potential to give better efficiencies than conventional jigs.

The areas of optimisation considered to be of primary importance are the pulse rate; pulse amplitude and pulse shape (Nesbitt et al, 2005). These are parameters known to be important to conventional jigs, noted to be important in a recent theoretical study of the Gekko IPJ Coal Separator and confirmed by the current

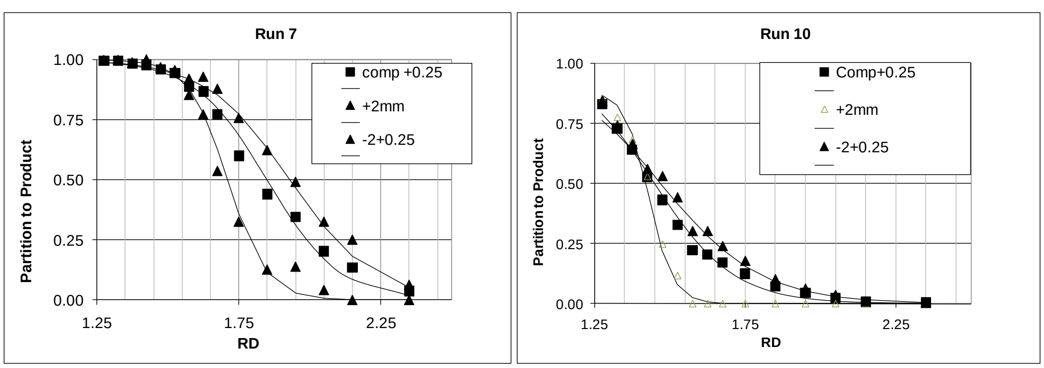


Figure 12. Preliminary separations using 10 tph Gekko IPJ Coal Separator

investigation. It is considered that there is considerable room for improvement for both D_{50} control and separation sharpness through optimisation of the abovementioned three parameters.

ACKNOWLEDGEMENTS

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