A preliminary investigation into the metallurgical efficiency of an enhanced gravity separator

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Synopsis

The cleaning of fine coal (-1000 μm) in today's coal preparation plants is an economically important factor. Coals with high ash contents are, in general, commercially undesirable. Current well-known techniques for treating fine coal include froth flotation and spirals. The primary critical factor with regards to spirals is the efficiency of the process whereas that of flotation, is the cost of the reagents used. Research into enhanced gravity separation techniques has resulted in several commercially available enhanced gravity separators. This project was based on a preliminary investigation into the feasibility of one such separator, to effectively treat fine (-500 μm) coal. Experimental variables included particle size and speed of rotation of the said instrument. The performance of the separator was compared to the results obtained from liquid density separations done for the two coal fractions evaluated. From the results obtained in this preliminary study it appears that the piece of equipment investigated does not measure up to expectations. Recommendations for further investigation include the evaluation of the instrument on other South African coals to obtain conclusive results.

Introduction

The cleaning of fine coal (-1000 μm) in today's coal preparation plants must be performed as stringently as possible, as it is this procedure that reduces the ash content and increases the market value of the product. New de-ashing technologies are always being sought after and researched. Current techniques used include froth flotation and spirals. Froth flotation and spirals have drawbacks concerning either cost of reagents or poor efficiency[1]. Research into enhanced gravity separation techniques has resulted in several commercially available enhanced gravity separators[2]. These include the Multi-Gravity Separator (MGS), the Kelsey Jig, the Knelson Concentrator, and the Falcon Concentrator[2].

This project was based on a preliminary investigation into the feasibility of one such separator, to effectively treat fine (-500μm) coal. Experimental variables included particle size and speed of rotation of the instrument. The study involved the comparison of the efficiency in de-ashing and recovery, obtained from this instrument, to that obtained from density separations.

Background

Investigations conducted during the past several years suggest that problems associated with surface-based separation processes, such as froth flotation, may be overcome by using enhanced gravity separators (EGSs)[3]. These devices, which were originally developed in the minerals processing industry, are capable of upgrading particles once believed to be too fine for water-based gravity separators[4]. Commercially available units include the Kelsey Jig, the Knelson Concentrator, the Mozley Multi-Gravity Separator and the Falcon Concentrator. These units utilize extremely high gravitational forces, uncommon in the industry. This, combined with large throughput capacities, makes EGSs the equipment of choice for the recovery of fine slurries and minerals[5]. The use of a high gravitational force enables the units to recover ultra-fine liberated particles and make efficient separations, even when other gravity processes are unsuitable[4]. The physical separation process is effective, proven and simple[4]. The machine investigated, for the purposes of this project, employs only one basic moving part and does not require the addition of chemicals or other consumable reagents. Thus the operating costs are low, which increases the feasibility of the equipment for utilization in the beneficiation environment.

Experimental

The experimental procedure involved several key steps that were crucial to the success of this investigation. These were executed carefully in the following order.

* *Sasol Technology R&D.*

- *Coal sample preparation*—The coal sample was crushed, screened and split using conventional methods into two size fractions, viz. -150 μm and -500 μm+150 μm
- *Density separation*[6]—This analysis was carried out to obtain a densimetric curve for the coal utilized. The efficiency of the instrument being investigated, in the removal of ash, is determined by the comparison of said instrument test results with the densimetric analysis results. Solutions of densities ranging from 1.3 g/cm^3 to 1.9 g/cm^3 were used to obtain the respective float and sink fractions. Recovery and ash analyses were then conducted on these fractions
- *Instrument testing*—The procedure for the separation of coal from its inorganic matter, using this particular separator, is relatively simple. A slurry, containing 1 kg of coal, was fed into the equipment, which was set at a back pressure of 0.5 psi. A light and heavy fraction was recovered respectively. The lighter fraction was concentrated through flocculation. This procedure was repeated twice more. Hence, three heavy fractions and a final product were obtained. Samples were run at 43 Hz, 53 Hz and 63 Hz for the -500 μm +150 μm sample, and at 53 Hz, 63 Hz and 73 Hz for the -150 μm sample. The fractions were dried, weighed and analysed for percentage ash. The effectiveness of the instrument was determined by the amount of ash removed from a given sample as a function of recovery
- *Maceral analyses*[7]—Maceral analyses of each of the head samples, products and discards were carried out on prepared polished grain mounts (or pellets). The coal was crushed and embedded in a mounting medium and the surface was polished for microscopy. The analysis involved counting a thousand points on a grain mount that was covered by evenly spaced traverses, using a mechanical stage. Each time the centre of the image fell on a maceral, that maceral was entered into a point counter. The result was a volume percentage of each of the different macerals present in the sample.

Results

The experimental results, which include mass recovery data, as well as ash analysis data, are presented with the corresponding discussions.

- *Coal analyses*—The -150 μm fraction had an ash content of 46% in the head sample, and the -500 μm + 150 μm fraction, an ash content of 37%. This observation is in agreement with comparative findings by other authors using a similar coal feed[8].
- *Density separation*—The results of the densimetric analyses are presented in Figure 1 and Figure 2, for the -150 μm and -500 μm+150 μm samples, respectively.

From Figure 1, it is clear that, for the -150 μm fraction, an ash content of ~23% is expected at a mass recovery of ~80%. It is expected that the mass recovery will be <40%, if an ash content of <15% is desired.

From Figure 2 it can be deduced that for the 500 μm + 150 μm fraction, an ash content of ~28% is expected at mass recoveries of ~80%. It is also evident (from Figure 2) that low ash contents (<12%) are expected at mass yields of <50%.

The differences in ash content between the two samples, at comparative mass recoveries, could probably be attributed to the differences in the extent of liberation of the mineral matter between the two fractions (See Table I and Table II).

- *Instrument testing*—Ash analyses of all the heavy fractions allowed for a 'calculated estimate' of the ash content of the product to be determined. These are presented in Figure 3 and Figure 4, for the -150 μm and -500 μm + 150 μm samples, respectively, together with the product recoveries.

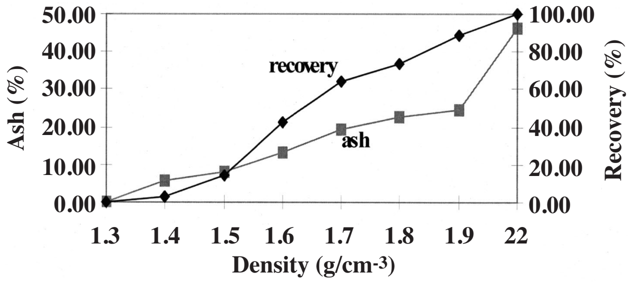

Figure 1—Densimetric analyses of the –150 μm coal fraction

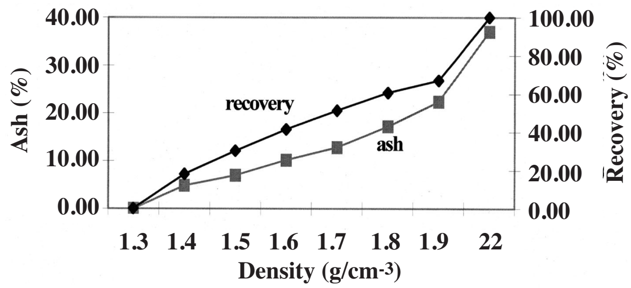

Figure 2—Densimetric analyses of the +150 μm–500 μm coal fraction

Table I

Mineral matter distribution (% by vol.)

Sample	Organic matter*	Carbominerite**	Rock ***
-500 μm + 150 μm Head	54.6	13.6	31.8
-500 μm + 150 μm Discard	56.4	13.6	30.0
-500 μm + 150 μm Product	78.6	12.8	8.6
-150 μm Head	32.0	18.0	50.0
-150 μm Discard	21.6	13.6	64.8
-150 μm Product	42.8	21.4	35.8

*Coal particle containing <5% mineral matter, or organic matter only.
** Carbominerite refers to a single particle containing both mineral and organic matter bound together.
*** Rock refers to particles >75% mineral matter, or no organic matter.

Table II

Maceral group analysis (% by vol. mineral matter free)

Sample	Vitrinite	Liptinite	Inertinite
-500 μm + 150 μm Head	39.2	3.6	57.2
-500 μm +1 50 μm Discard	43.6	1.4	55.0
-500 μm + 150 μm Product	41.2	3.6	55.2
-150 μm Head	21.0	4.1	75.0
-150 μm Discard	23.0	4.5	72.5
-150 μm Product	20.0	6.0	73.9

From Figure 3 it is clear that the lowest ash content attainable (41.5%) for -150 μm sample, is at a speed of 53 Hz. This ash content is four percentage points lower than that of the head sample (46%).

From Figure 4 it is clear that, at a speed of 63 Hz, an ash content of 35% can be achieved for the -500 μm + 150 μm sample. This value is two percentage points lower than that of the head sample (37%).

It is clear that on average, the mass recovery of the product, at any speed for either of the two coal fractions evaluated, is 81%. According to density separation results the corresponding ash content of the products after treatment should be ~25% for each coal fraction. The separator investigated clearly did not meet the theoretical values reflected by the densimetric analyses of the samples.

- *Maceral analyses*—Maceral analyses were done primarily to determine whether a change in the proportions of macerals was observed.

From Table I it is evident that a significantly lower content of mineral matter (quartz, pyrite and carbonates) was observed in the products for both coal fractions than in the respective head samples. This result implies that the equipment investigated did remove a significant amount of free mineral matter.

According to the results summarized in Table II, the proportions of the macerals, compared between the products and the relevant head samples, were not affected significantly by the instrument.

Conclusions

Several conclusions can be drawn from this experiment.

- The coal used had high levels of ash (37% and 46%).
- High product mass recoveries (~81%) were obtained with the enhanced gravity separator.

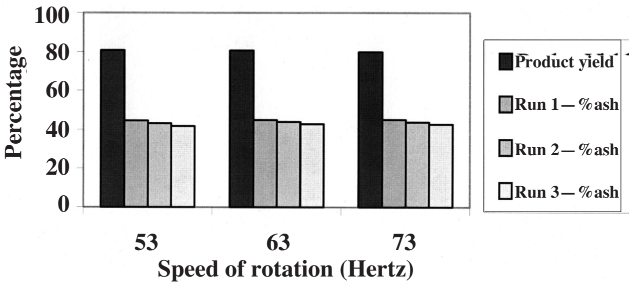

Figure 3—Showing calculated ash content of products and mass recoveries for the -150 μm coal fraction

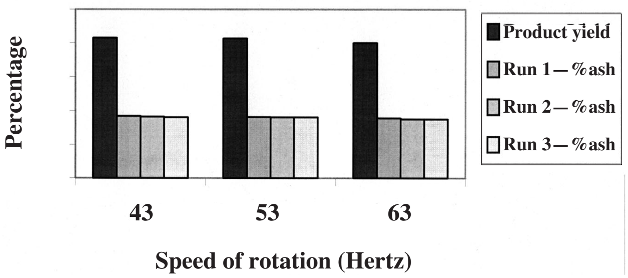

Figure 4—Showing calculated ash content of products and mass recoveries for the +150 μm -500 μm coal fraction

- Compared to densimetric results for the two coal fractions, the instrument's performance in terms of ash removal did not meet expectations.
- Significant amounts of free mineral matter were removed from the samples.
- Non-liberated mineral matter content was not significantly reduced.
- No significant change in maceral distribution was observed for either coal fraction after treatment.

Recommendations

The results obtained are not conclusive enough to draw any concrete deductions, in terms of the efficiency of the separator investigated, and further work still needs to be done. The following steps are recommended to ensure conclusive results:

- Several new samples of coal should be evaluated
- The size fraction -1000 + 150 μm should be used, as this fraction better represents the feed to the spirals
- An ash by size analysis of the head sample and products for the -1000 + 150 μm sample should be included.

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Mine feasibility study shows coal expansion likely to go ahead*

Scheduled for completion in May this year, a R2-million feasibility study by Snowden Mining Industry Consultants has unearthed no major obstacles with regard to the planned expansion of Total Coal Holdings, Forzando South Coal Project.

Earmarked to fulfil Total Coal Holdings, commitment to the expanded Richards Bay Coal Terminal by late 2003, the South project will have to start producing export quality coal within 18 months of completion of the feasibility study. This means that orders for primary infrastructure could be expected as early as the fourth quarter of 2002.

Infrastructure requirements include a 5 km conveyor belt system, the sinking of the shaft, mine operation and operation of the new processing plant, which is likely to be constructed by Dowding, Reynard and Associates as a mirror image of the existing plant. Disposal of coal residues will also be linked to existing infrastructure, which will reduce the life of the disposal site to 6 years, while saving on capital expenditure at the outset of the expansion project.

'Because of solid sandstone layers in the area, mining will consist of conventional, semi-mechanized bord-and-pillar methodology', reports Snowden Mining Industry Consultants Project Manager, Alistair Forbes. 'Full mechanization will not be possible, as we have identified a coal/sandstone layer that is too hard to mine with mechanized equipment. Twelve additional holes had to be drilled to determine the extent of this parting.'

Snowden Mining Industry Consultants involved all stakeholders, from government level to labourers and local communities, from an early stage to ensure continued goodwill towards the project.

The study even produced unexpected benefits for a local dairy farmer and exporter of embryos when it identified excessive fluoride levels in the multi-million Rand agricultural operation's primary borehole. It is hoped that various mysterious health problems plaguing the farm's livestock for years will now be eliminated through the use of an alternative water source.

'I think the fluoride case just underlines the success that we have been achieving with this project to date', enthuses Forbes. 'I am confident that Forzando South will become a primary source of export coal within a few years.'

Conceptual design has been completed, including shaft location. 'We have placed the shaft right next to an existing access road on the north side of the river', says Forbes. 'This means that impact on the river will be minimized and the only obstacle that the 5 km conveyor link will need to deal with is the railway line to Richards Bay.'

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Low cost route for production of high-quality EMD development*

Minerals researcher MINTEK has developed a process to produce Electrolytic Manganese Dioxide (EMD) from low-grade manganese ores that eliminates the costly up-front pyrometallurgical pre-reduction step.

The process involves a reductive leach and some purification steps. which are applied to the manganese leach solution to remove impurities and produce a suitable manganese electrolyte for the production of high-purity EMD. The reductive leaching operation is controlled to minimize the formation of dithionates, and any excess quantity of dithionate is destroyed to a sufficiently low level prior to the production of the EMD.

The process was developed by Mintek for a client in Australia, and has been successfully piloted in Australia. The client is currently negotiating contracts with battery manufacturers for the offtake of the product, and is currently looking to secure finance to build a production facility in Australia.

The process is also undergoing pilot-scale trials at a plant in Colombia, and has been successfully tested on South African manganese ore at Mintek.

For more information, please contact Roger Kuch at Mintek on (011) 709-4163. ◆

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