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Processing low-grade coal to produce high-grade products

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Synopsis

South Africa's best-quality coal, located in the central Highveld basin, is becoming depleted and alternative sources of coal, such as the Waterberg coalfield, will have to be developed to supply the country with coal in the future. The quality of the coal being mined in the central basin is gradually becoming poorer. This necessitates that more of the coal be processed to improve the quality to meet customer requirements. The challenge to the coal processing industry is to process low-yielding coals to produce good-quality products and at the same time ensure that coal mining remains economically viable. This requires that more cost-effective coal processing technologies be investigated and implemented.

Keywords

low-grade raw coal, new developments, low-cost coal processing technologies, dry processing of raw coal.

Introduction

South Africa's main sources of coal supply for the last century have been the Witbank, Highveld, and Ermelo coalfields. These coalfields have been extensively mined to produce the coal required to satisfy the needs for power generation and other industrial requirements, and also to establish a competitive share for South African coal in the international export market. The remaining reserves of coal in these coalfields will eventually become depleted – it is predicted that this will happen by about 2040. South Africa does, however, still have extensive reserves of coal in other areas, namely the Waterberg and Soutpansberg coalfields, while coalfields located in the Springbok Flats, the Free State, and Molteno area remain largely unexploited. The coal from some of these areas is, however, of relatively low quality compared to the coal from the Witbank area.

Since the coal found in the Waterberg, Soutpansberg, and other coalfields differs from the coal traditionally mined, new techniques will be required in the future to mine, process, and utilize the coal. It is expected that the quality of the coal as-mined will become increasingly poorer while the coal market will become increasingly more demanding in terms of the quality of the product. This will therefore present significant challenges to the coal industry.

History of coal processing in South Africa

In the early days of coal mining in South Africa, coal was selectively mined to satisfy the requirements of local industries – mainly the gold and diamond mines and the transport industry. The requirement was for coarse coal and it was customary to screen the coal finer than about 6 mm, which was termed 'duff', from the coal as- mined. The coarse coal was supplied to the end-users while the duff, which comprised a significant portion of the run-of-mine coal, was discarded. Selective mining resulted in the sub-optimum utilization of coal reserves, and mine owners realized that whole-seam mining would be a more sustainable option. Mining the complete coal seam, however, resulted in lower quality coal and hence some form of upgrading of the coal was needed. Hand-picking (Figure 1) was the method first employed to achieve this objective, but improved coal processing techniques eventually followed. The first coal preparation plant in South Africa was a jig plant constructed in the Witbank area in 1909 (Coulter, 1957). The next major advance in coal processing was the commissioning of a Chance washer in the Vereeniging area in about 1935 (Coulter, 1957). Other coal processing plants in the Witbank area and in the former Natal province followed.

In response to a growing demand for coal and the ever-increasing pressure to supply good-quality coal, jig washers were installed at a number of coal mines. Following the introduction of dense medium processing using magnetite as the medium during the 1950s, the jigs were gradually replaced by the more efficient dense medium process. The

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Figure 1 – Hand-picking at Springbok Colliery

major change in the South African coal processing industry came about as a result of a contract concluded with a consortium of Japanese steel mills during the early 1970s for the supply of 2.5 Mt of low-ash coal per annum to be used as a blend coking coal. The duration of the contract was 10 years, and the coal was to be produced from the Witbank No. 2 seam. This contract led to the establishment of the dedicated coal railway line from the Highveld to Richards Bay and the Richards Bay Coal Terminal (RBCT). Very efficient coal processing techniques were required to process the difficult-to-wash No. 2 Seam coal in order to produce the low-ash coal required for the Japanese steel industry. Research conducted by the Fuel Research Institute of South Africa (FRI) during the late 1950s and 1960s was successfully implemented to satisfy this requirement. The initial focus of the FRI research was not the Japanese market, but was aimed at extracting coking coal from the Waterberg coalfield for use by the local iron and steel industry. This know-how came in handy for the Japanese contract and was also successfully implemented when Grootegeluk Mine came into production in the late 1970s. South Africa's coal processing industry therefore became equipped to effectively process difficult raw coals to produce high-quality products.

Current coal processing practice

South Africa today has approximately 60 coal preparation plants, most of which are located in the Witbank area. Many of these plants produce export thermal coal, which is exported via RBCT – currently a total of some 70 Mt/a. The export coal typically has a heat value of 6000 kcal/kg, which requires the raw coal to be processed at a low relative density. Most of the mines employ two-stage processing plants, with the first stage processing the raw coal to yield an export product and the second stage re-processing the rejects from the first stage at a higher relative density to produce a thermal coal for Eskom. There are also a growing number of small plants that only produce coal for Eskom. Most of the export plants, as well as the Eskom-only plants, use dense medium drums and/or cyclones for processing coarse coal and spirals to process fine coal.

There are a number of smaller plants in the Witbank area, and also a few in KwaZulu-Natal, that produce sized products for the inland market. These plants tend to be equipped with a single Wemco drum to process coarse coal, dense medium cyclones to process the small coal, and spirals to process the fine coal. The drum product is usually screened to produce large and small nuts, while the cyclone product is screened into peas and duff. The spiral product is usually added to the duff.

New developments in coal processing

As mentioned previously, the quality of raw coal being mined continues to decrease, and several mines extract coal pillars left from previous bord and pillar mining operations. The product yields obtained from the raw coal are lower than in the past and processing of the coal is becoming more of a necessity. Since the coal is becoming more difficult to process and product yields are low, there is increasing pressure on the profitability of mines and as a result, low-cost processing techniques are being evaluated and implemented. Some of the technologies recently implemented in South Africa include the 3-product dense medium cyclone and dry beneficiation.

The 3-product dense medium cyclone was developed in Russia during the 1970s, but only found widespread application in China in the past 10 or so years. The unit is essentially a Larcodems-like cylindrical cyclone with a conventional conical cyclone attached to the sinks outlet. The raw coal and medium is pumped to the primary cylindrical cyclone, where a low-density separation is effected to yield an export-quality coal. The sinks and part of the medium then enters the conical cyclone, where a high-density separation is effected on the coal to yield an Eskom product and a final reject. The unit therefore allows two separations to be carried out with a single medium circuit, which results in significantly lower capital and operating costs. The 3-product cyclone in operation at Umlalazi Mine is shown in Figure 2.

The capital cost of new plants is an important consideration and has to be kept as low as possible while still maintaining efficient processing of difficult raw coals. This is achieved by simplifying plant configuration through the use of large, high-capacity processing units such as large-diameter dense medium cyclones and large-capacity screens. This reduces the number of equipment items in a plant and still enables effective separation of coal.

South Africa is a water-scarce country and the coal industry is under pressure to reduce the amount of water consumed for coal processing. In this regard, a number of coal processing plants have installed filter presses to close their water circuits. By filtering the slurry produced during coal processing rather than disposing of it in slurry ponds, water consumption is reduced by a factor of about three. An added advantage is that the product obtained from the filter may be saleable. The filter press in operation at Hakhano Mine can be seen in Figure 3.

Dry processing of coal requires no water and dry processing techniques are therefore very attractive considering our climatic conditions. Two dry processing technologies have been evaluated and implemented in South Africa, namely the FGX dry coal separator and X-ray sorting. The FGX unit is suited to processing of -80 mm raw coal while the X-ray sorter is well suited to de-stoning or pre-beneficiation of coarse coal. Further advantages of dry processing are that the capital and operating costs are much lower than dense medium processing; the product coal stays dry, which effectively increases the heat value of the coal; and no slurry is produced, which lowers the environmental impact of coal processing. Unfortunately, the separation efficiency of the available dry processing technologies is inferior to that of dense medium separation, and these technologies are not generally applicable to all raw coals. The FGX plant at Middelkraal Colliery is shown in Figure 4.

Some of the mines that exclusively process coal for Eskom need not process the complete size range of raw coal and employ partial washing. In partial washing, the finer sizes of coal are dry-screened from the plant feed and report directly to the product conveyor. The coarser coal is processed and the resulting product blended with the fine raw coal to constitute the final Eskom product. The size at which the coal is dry-screened depends on the specific quality of the raw coal and can vary between 4 mm and 40 mm. Dry screening at small aperture sizes is not easy, but the Bivitec and Liwell Flip-Flo screens have proven capable of this duty.

Future needs

It is expected that coal processing will become more difficult in future as the quality of raw coal mined continues to decline. Coal processing plants will have to contend with lower yields and more difficult-to-process coal. At the same time, strict product quality specifications will have to be maintained.

The separation efficiency of the processes employed will become even more important and it will be necessary to balance separation efficiency against capital and operating costs. The low cost of dry processes make them very attractive, especially for small mining companies, but the low separation efficiency of these processes may make them uneconomical in the long run. An efficient dry process is therefore required. Dry dense medium separation offers good efficiency but is still unproven in practice. A pilot-scale dry dense medium plant is in operation in China and the South African coal industry, through the Coaltech research programme, plans to evaluate this technology in the near future.

Figure 2 – 3-product cyclone at Umlalazi Mine

Figure 3 – Filter press at Hakhano Mine

Figure 4 – FGX plant at Middelkraal Colliery

Due to low-yielding raw coal and resulting low product yields, it will be necessary for coal processing equipment to be able to cope with high amounts of reject coal. High spigot-capacity dense medium cyclones or suitable substitutes will be required.

Improved fine coal beneficiation and dewatering techniques will be needed as the amount of fine coal in run-of-mine coals is expected to increase further – especially in those mining operations where remnant pillars are being re-mined. An additional factor to contend with in the case of pillar re-mining operations is the influence of weathering and spontaneous heating of coal. It is further anticipated that more fine coal will have to be utilized in power generation, and methods to improve the transport characteristics of fine coal will therefore have to be investigated.

The effective recovery and re-use of water in coal processing plants will become even more important. It is also anticipated that the cost of water, especially in the Waterberg area, will increase significantly in future.

Improved methods for the disposal and/or use of discards and slurry will be required to ensure that coal mines comply with ever-increasing environmental concerns.

Conclusion

Mining conditions in the traditional mining areas will become more demanding in future and mining operations from new coalfields will have to commence. This will require coal processing engineers to find new and improved methods to process low-grade raw coals to yield high-grade products within ever-increasing economic and environmental challenges.

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