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Optimisation of the three-product cyclone at Greenside Colliery

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Abstract. Greenside Colliery implemented the three-product cyclone in 2013 to reduce discard footprint. Over time, changes in primary product specifications and inherent ROM characteristics caused a lower quality middling fraction below RB4 specifications. This required optimising of the three product cyclone operational settings to mitigate the above impacts. The objective of this test work was to optimise the middling product via two steps, namely (1) manipulating the vortex finder length and (2) testing different water injection flow rates. Four vortex finder lengths were tested and the results showed that a 75% (10.5 cm) vortex finder length was the ideal setting. Similarly, for the water injection, four flow rates were tested resulting in 50 m3/hr being the ideal flow rate. At these settings, the secondary cyclone achieved a calorific value (CV) within the required RB4 specifications. Optimising the three-product cyclone is essential for the revenue of the plant and to ensure that the middlings revenue stream is maximised. Continuous test work is recommended because, as ore types and characteristics change, the optimum secondary cyclone settings will need adjustments. As well as changes within the process, any changes that impact the DMS will necessitate a review of the secondary cyclone settings

1 Introduction

The dense medium separation process (DMS) is considered a mature technology, a staple in diamond and coal processing plants since it was patented in the 1940s [1] . Many processing plants utilise cyclones to separate the product from discard and, while cyclones are efficient, they struggle when processing a mixture of materials, resulting in the need for a fines and coarse DMS in most plants. In the 2000s, when the three-product cyclone - originally designed in Russia and popularised in China [2] – appeared, it looked like the solution to the standard cyclone inefficiencies. South African processing plants, including Thungela Greenside Colliery (formally Anglo Coal), implemented the three-product cyclone in their plants.

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1.1 Background

The three-product cyclone, as depicted in Figure 1 below, consists of a cylindrical primary vessel attached to a conventional cyclone. Raw coal and medium is fed to the primary cyclone where a high CV product (clean coal) is recovered as well as discard (refuse) that feeds the secondary cyclone. From the secondary cyclone, a middlings product and final discard is recovered. The three-product cyclone can be gravity-fed or pump-fed. Using the three-product cyclone maximises the produced product and, in essence, reduces the discard produced and discard footprint.

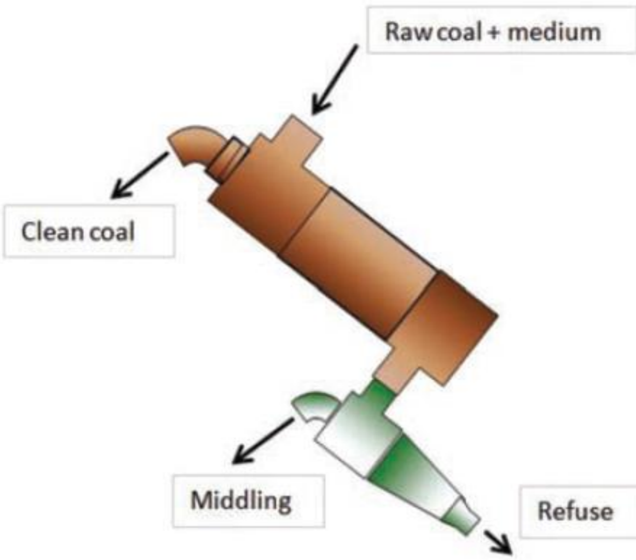

Fig. 1. Three-product cyclone layout [2]

In its effort to reduce the discard footprint, Greenside Colliery implemented the three-product cyclone in its processing plant in 2013. For years, Greenside produced a RB1 primary product and a RB4 middlings (secondary product). Due to business needs, Greenside has had to change to a RB2 primary product while maintaining an RB4 secondary middlings product. The impact of this change implies less yield in the middlings fraction and potential impacts on quality of the subsequent middlings product to meet an RB4 specification for both export and/or domestic markets. Due to the primary product change, the middlings quality was indeed below the RB4 quality and domestic market sales qualities for the middlings fraction. Hence this necessitated the optimisation of the operating parameters of the three product cyclone to ensure a viable secondary/ middlings product quality with sale value within the domestic and export markets.

1.1.1 Greenside plant flow diagram

Figure 2 below is a depiction of the Greenside plant. Greenside is a modular plant with three modules, each one a three-product cyclone with a processing capacity of 250 t/hr.

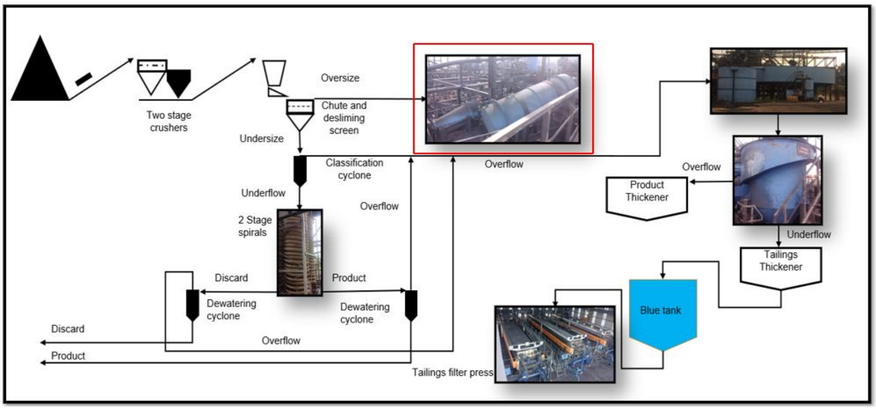

Fig. 2. Greenside plant flow diagram

The primary product is conveyed to the Rapid Loading Terminal (RLT) via a system of conveyors. The middlings product is currently predominantly for the domestic market and is transported via trucks.

1.2 Objectives

The objective of this project was to upgrade the middlings (secondary product) CV to a RB4 equivalent middlings quality to meet the business requirement. This was accomplished through the completion of the following steps:

- Manipulation of the vortex finder length
- Optimisation of the water injection in the secondary cyclone

2 Methodology

To optimise the three-product cyclone, module 2 was used as the test module to ensure equipment conditions were kept constant. The following steps detail how the test work was conducted.

2.1 Vortex finder length manipulation

The secondary cyclone vortex finder length was changed weekly over a period of four weeks, while water injection volumes were kept constant during the trial. Table 1 below shows the steps taken to measure the vortex finder length and the calculations used to determine the vortex finder openings. As seen in Table 2 the length percentages, calculated in centimetres, were utilised in the test work.

Table 1. Steps for changing the vortex finder

Steps	
1	Close vortex finder 100%
2	Measure the distance of the thread from start to the inside of the wheel (x)
3	**Divide x by 4 to get the distance of the intervals (call it y)**
4	For 0% open, leave closed
5	25% open - open one y measurement
6	50% open - open two y measurements
7	75% open - open three y measurements
8	100% open - open four y measurements or just x.

Table 2. Length % with cm

Opening	0%	25%	50%	75%	100%
Length (cm)	0	3.5	7	10.5	14

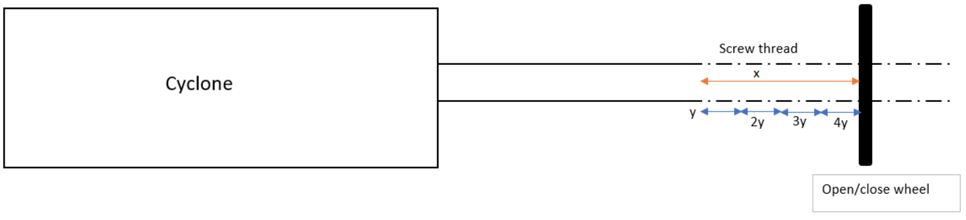

Fig. 3. Schematic of the secondary cyclone vortex finder

Figure 3 above is a schematic of the vortex finder depicting the different length positions. Daily composite samples were collected and analysed in both the onsite lab and the offsite lab (Bureau Veritas). The results were analysed and will be discussed in the results section of this paper.

2.2 Secondary cyclone water injection

Similarly, the water injection test work was conducted over four weeks, with changes in volumes made weekly. The optimum vortex finder length was used for the duration of the test work. Table 3 below shows the different water injection settings that were tested during the trial.

Table 3. Water injection volume settings

Week	Water injection volume (m3/hr)
Week 1	45
Week 2	50
Week 3	55
Week 4	60

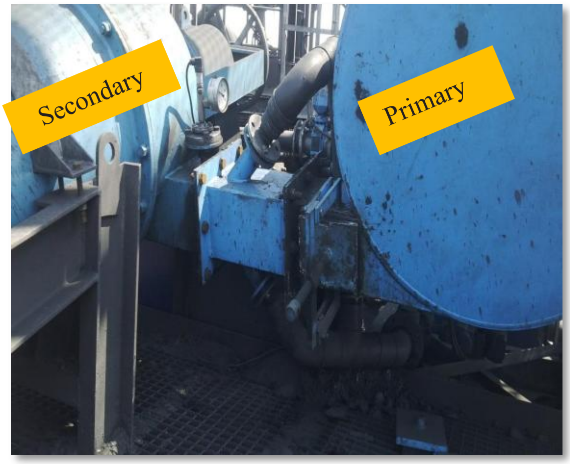

Fig. 4. Module 2 primary and secondary cyclone

Figure 4 above shows a portion of the three-product cyclone, with the primary and secondary cyclones and the pipes responsible for water injection. Daily composite samples were collected and analysed in the onsite and offsite labs. The results were analysed and will be discussed in the results section of this paper.

3 Results

Please note for confidentiality of Thungela's IP actual CV & Ash values are not included in the report. CV and Ash will be referred to as X and Y respectively.

3.1 Vortex Finder length

Before conducting the test work, Module 2 qualities (CV and Ash) were collected. This base data was used for comparison with the results as changes were implemented. The data was collected weekly for four weeks as seen in Figure 5 below.

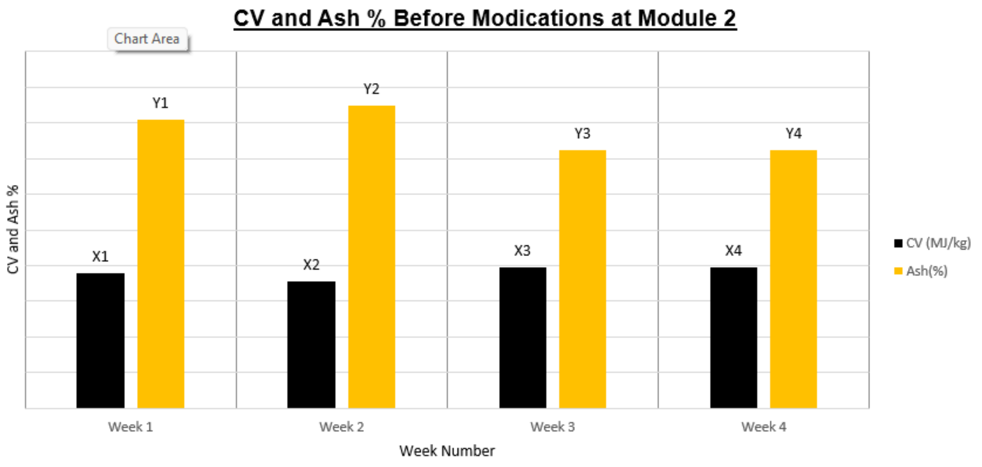

Fig. 5. Module 2 qualities before modifications

The data collected before changes were made was essentially collected at a 0% vortex finder opening. Over the four weeks, Module 2's CV averaged a CV and ash below the required RB4 specifications. Week 4 recorded the highest CV before modifications were Implemented.

As detailed in the methodology, the vortex finder was tested at four different lengths. In Figure 5 the results from the different lengths are compared. At 75% open, module 2 secondary cyclone showed the highest CV X4 and the lowest ash percentage Y4. From the average qualities before modifications, a 9% increase in CV was observed while a 17% decrease in ash noted.

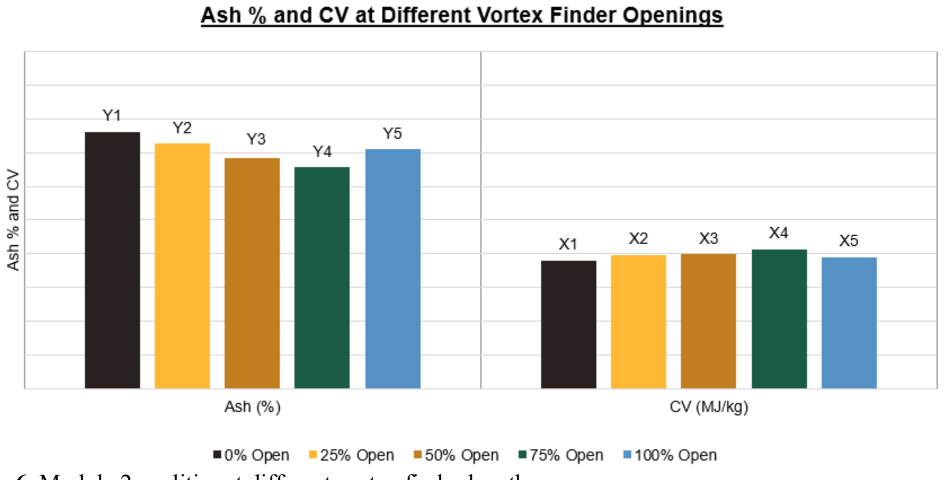

Fig. 6. Module 2 qualities at different vortex finder lengths

Increasing the length of the vortex finder reduces the chances of feed short-circuiting into the overflow and dropping the qualities of the product [3], [4]. However, increasing the vortex finder length excessively increases the chances of sinks (discard material) reporting to the overflow, also dropping the product qualities. This phenomenon can be seen when comparing the qualities recovered at 75% open and 100% open vortex finder. When the vortex finder is fully open a decrease in CV is noted, hence a delicate balance is required.

For this test work a 75% open, which translates to 10.5 cm, proved to be the best vortex finder length.

3.2 Water injections

The next stage of the optimisation process was the water injection. Over an additional four weeks, different water volumes were tested and the results are represented in Figure 6.

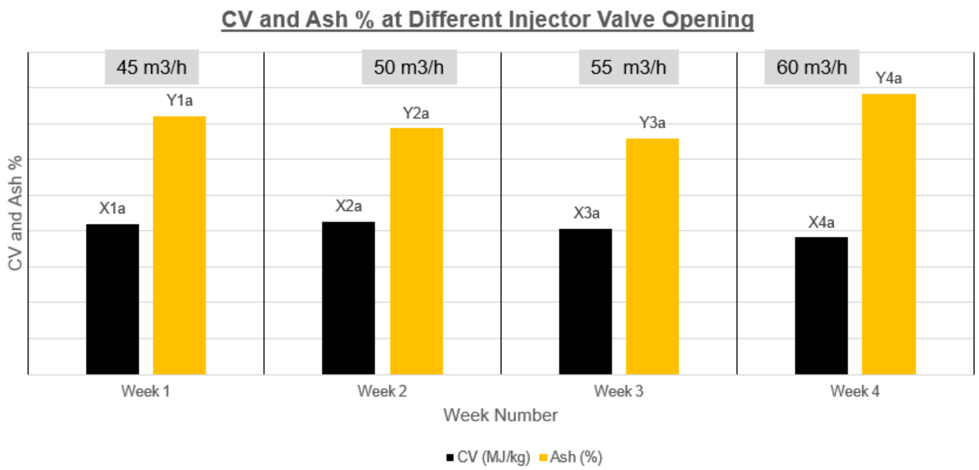

Fig. 7. Module 2 qualities at different water injection volumes

From the test work, the results show best qualities were observed at a water injection rate of 50 m3/hr. At this flow rate, CV X2a and ash Y2a were recorded, these qualities were with the required RB4 specifications. Injecting water at a tangent to the cyclone cone helps move the material in the sinks and increases the efficiency of separation, resulting in a higher quality product [5]. An important factor with the water injection in the three-product cyclone is to ensure all water added to the secondary cyclone is removed from the system so as not to impact the primary density control. For this test work, at a flow rate of 50 m3/hr, optimum results were received.

A comparison of Module 2 qualities before the modifications and after the modifications is depicted in Figure 7 below. A clear increase in CV can be seen after the vortex finder length and water injection have been optimised. 75% open on the Vortex finder and 50m3/hr flow rate were found to be the optimum settings, achieving a 12% increase in CV and 14% reduction in the ash percentage. An interesting point in the data set is that the 60m3/hr setting resulted in a drastic decrease in qualities. This can be an effect of increased dilution which essentially shifts the cut point density inside the cyclone and allows near dense material to report to the floats as opposed to the sinks hence a reduction in the CV and increased ash percentage.

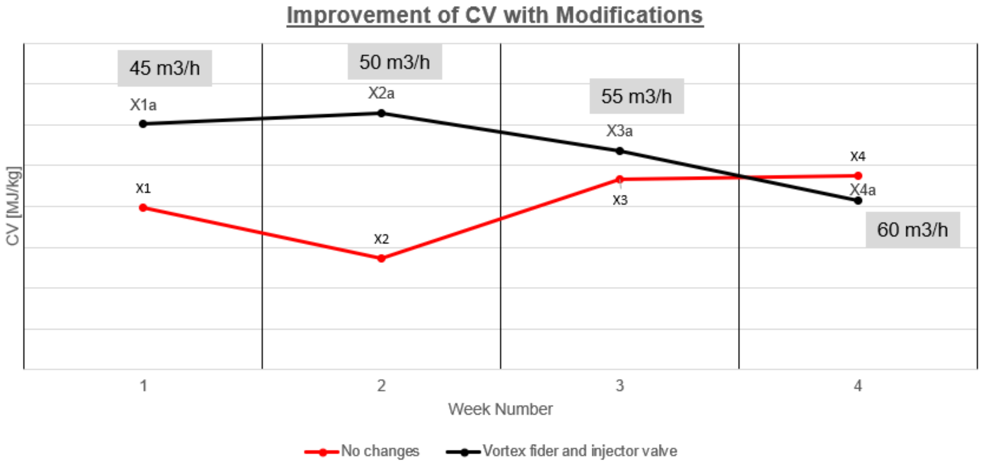

Fig. 8. Module 2 qualities before and after modifications

The increase in quality is directly linked to financial gain as higher-quality material is sold at higher prices. Middlings within the required RB4 specifications can be sold at market prices both for export and domestic markets.

4 Conclusions

The objective of this test work was to optimise the middling product via two steps, namely (1) manipulating the vortex finder length and (2) testing different water injection flow rates. Both steps were completed, resulting in the objective being achieved. From the test, 75% open on the Vortex finder and 50m3/hr flow rate were found to be the optimum settings, achieving qualities within the RB4 specifications. Optimising the three-product cyclone is essential for the revenue of the plant, ensuring the middlings revenue stream is maximised.

Continuous test work is required as ore types and characteristics change the optimum secondary cyclone settings will need adjustments. As well as changes within the process, any changes that impact the DMS will necessitate a review of the secondary cyclone settings. Another avenue for further research is other possible variables that can impact the efficiency of the 3-product cyclone.

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