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Nicole Prochnau  
*Wirtgen Australia Pty Ltd*

Ross Carter  
*Wirtgen Australia Pty Ltd*

Hermann Volk  
*Wirtgen GmbH*

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# IMPROVING PERFORMANCE IN THIN SEAM OPEN CUT MINING – APPLICATION OF PICK BASED CUTTING TECHNOLOGY

Nicole Prochnau<sup>1</sup>, Ross Carter<sup>2</sup> and Hermann Volk<sup>3</sup>

**ABSTRACT:** With the current challenges facing the Australian coal industry, a major Australian coal miner has achieved significant improvements from the implementation of a continuous mining system, a Wirtgen Surface Miner 4200 SM, at an open cut coal mine in South East Queensland. Due to the multiple thin seam characteristics of the deposit, selective mining practices are critical. This often results in decreased productivity when using Conventional Mining (CM) equipment. The Wirtgen Surface Miner (WSM) cuts, crushes and loads coal and Interburden (IB) onto a truck in a single step and thereby replaces multiple CM equipment for ripping, stacking and loading. This paper presents an in-field study, assessing the benefits gained from implementing the 4200 SM. When implementing new technology it is important to evaluate its performance compared to the existing system. The trial program was therefore structured around Key Performance Indicators (KPIs) referring to the CM system. The evaluation contains empirical assessments combined with theoretical calculations and literature research. A key challenge of the project was to compare a continuous mining system, i.e. the 4200 SM, against a discontinuous, multi-handling mining system. A commensurable evaluation of both mining systems was achieved by defining a CM-unit. Objectives of the evaluation were productivity, unit costs, Health-Safety and Environmental (HSE) performance, deposit recovery, Run-Of-Mine (ROM) coal quality and impacts on the Coal Handling and Processing Plant (CHPP). The WSM has demonstrated increased productivity, improved HSE performance, minimised loss and dilution, positive impacts on the CHPP, more consistent particle size distribution containing more target product size, as well as significant mining unit cost savings compared to the conventional dozer rip, stack and load process. On average, the mining unit costs are reduced by about 60%, considering different rock properties in coal and IB. The fuel usage per volume mined decreases even more significantly, resulting in a reduction of carbon emissions.

## INTRODUCTION

The New Hope Group has recently successfully implemented a Wirtgen Surface Miner (WSM) into the existing mining fleet at its New Acland Coal mine (NAC). The characteristics of the deposit are banded coal plies with thinly bedded sandstone, siltstone and mudstone layers. A total number of 47 plies exist. Coal seam thicknesses vary from less than 0.2 m to about 2 m. This multi thin seam operation requires selective mining practices (Pippenger 2014).

A Wirtgen 4200 SM commenced operation at NAC in June 2014. A six-month trial period was part of the implementation process on site. During that trial period, the performance of the WSM was analysed to evaluate the outcomes against defined Key Performance Indicators (KPIs). Operation of the WSM was trialled in a variety of operating conditions in overburden, Interburden (IB) and coal. The objective of this paper is the analysis of the 4200 SM performance during the first four months of implementation. The project aimed at identifying benefits that the high capacity selective WSM provides to the overall production cycle at NAC. Major expectations related to the WSM mining system were:

- Better coal recovery (less loss and dilution);
- Increased productivity;
- Unit cost savings;

<sup>1</sup> Project Engineer, Wirtgen Australia Pty Ltd, [nprochnau@wirtgen-aust.com.au](mailto:nprochnau@wirtgen-aust.com.au).

<sup>2</sup> Manager Surface Mining, Wirtgen Australia Pty Ltd, [rcarter@wirtgen-aust.com.au](mailto:rcarter@wirtgen-aust.com.au).

<sup>3</sup> Product Manager, Wirtgen GmbH, [hermann.volk@wirtgen.de](mailto:hermann.volk@wirtgen.de).

- Decreased wear and better handling of ROM coal at Coal Handling and Processing Plant (CHPP) (cleaner coal, amount of fines and target particle size);
- Improved handling of seams that contain siderite intrusions;
- Less complex and more efficient mining due to less equipment involved; and
- Positive environmental impacts (e.g. less noise, carbon emission, less blasting).

The trial program was structured around KPIs referring to the Conventional Mining (CM) system. (Wirtgen Australia 2014) During the trial period, the CM process was also examined in detail to provide a basis for a direct comparison of both mining systems. The research project assessed the 4200 SM performance by making a series of comparisons between:

- CM of coal and IB, that utilises a combination of D11 dozers to rip and push the coal / IB and a front-end loader to load trucks; and
- 4200 SM mining of coal and IB, where the 4200 SM mills the coal / IB and directly loads the cut material into trucks.

Both mining systems were assessed regarding environmental, economic and operational parameters. The assessment was not limited to the actual mining process, but also analysed the impacts on the overall process cycle of the mine site.

### WIRTGEN SURFACE MINER TECHNOLOGY

Amongst various innovative mining technologies, the surface miner technology has gained considerable prevalence over the past decades (Williams *et al.*, 2007). Surface miners are commonly used in North America and Central Asia, in mostly soft rock operations. In Western Australia, a large fleet of WSMs with a hard rock cutting drum is employed in iron ore (Anon 2010). The German machine manufacturer Wirtgen GmbH is currently technology and market leader for surface miners (Berkhimer 2011 and Schimm 1999).

Surface miners perform rock-breakage by means of cutting. A rotating drum with cutting tools (i.e. picks) cuts the material. There are a number of manufacturers that distribute surface miners (Anon 2010). Each manufacturer has its own specific surface miner technology. The main difference is the drum position. Surface miners are available as front drum types, middle drum types and rear drum types. Another difference in the surface miner operating method is the type of material handling. The material is either deposited on the ground or directly loaded onto trucks by an attached conveyor belt.

WSMs look similar to cold milling machines used in road construction and their basic operation principle is the same. They combine cutting, primary crushing and loading in one single step. If direct loading is not desired, windrow machines are available that leave the cut material on the ground between the crawlers. Furthermore, WSMs with a conveyor have the option to side-cast the cut material (Wirtgen GmbH 2010). Wirtgen is the only manufacturer who offers all three material handling options (i.e. direct loading, windrowing, side-casting). The machine set-up can be seen in Figure 1 (Wirtgen GmbH 2010).

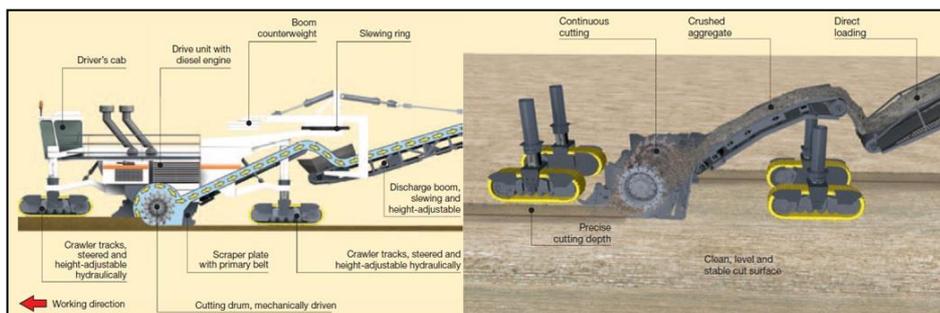


Figure 1: Wirtgen Surface Miner Technology (Wirtgen GmbH 2010)

The cutting drum is located between front and rear tracks, in the middle of the machine. This location, close to the centre of gravity, provides efficient transfer of the cutting forces because the whole machine weight and power is transferred into cutting force. Impact loads and shocks are well absorbed and high machine stability is achieved. Toolholders are mounted to the cutting drum in an application-specified layout. The toolholders are fixed to the drum in a helix layout that directly carries the cut material to the centre of the drum and further onto the primary conveyor. The actual cutting tools are round shank bits (i.e. picks) with tungsten-carbide inserts. The design of the cutting system varies depending on mine site conditions (Wirtgen GmbH 2010). The main design factors listed by Wirtgen GmbH (2010) are:

- Cutting tool type;
- Cutting tool holder type;
- Number of cutting tools (spacing);
- Angle of cutting tools; and
- Cutting drum rotation speed.

The 4200 SM implemented at NAC is a soft rock, direct loading machine with a 16 m discharge conveyor belt that has 180° slewing capacity. 130 -180 t payload size trucks are allocated to the WSM at NAC. However, WSMs are able to load 240 t size trucks. A boom counterweight ensures the machine's stability. The cutting drum has a width of 4200 mm and a diameter of 1860 mm including cutting tools. The drum is equipped with 62 cutting tools in total and rotates upwards. Cutting depths up to 830 mm can be achieved. The maximum operation grade is 20% and lateral inclination is limited to 8% (Wirtgen GmbH 2010). The rated power is 1194 kW (Wirtgen Australia, 2014). The 4200 SM cuts lanes out alongside each other. At the end of each lane, the 4200 SM cuts its own ramp and turns 180° around to cut the next lane. The ramp area and turnaround area is later ripped and stacked into windrows by a dozer and the 4200 SM picks up the windrows before cutting the next bench (Wirtgen GmbH 2010).

### CONVENTIONAL MINING SYSTEM

The existing CM system at NAC is a discontinuous process. Rock-breakage and loading occur in separate steps. The main production fleet for coal and IB consists of D11 dozers for rock-breakage and stacking and 992G front-end loaders for excavation. Haulage is carried out by 130 -180 t haul trucks. The CM system is operated in 150 m x 150 m blocks. There is only one mining step (i.e. rock-breakage and stacking or excavation) carried out in one block at a time. Multiple blocks are always held open for mining (Pippenger 2014).

Dozers play a major role at this mine site. They are used for ripping and stacking of coal and IB, which are a major component of the CM system. For loosening the rock for later excavation, the ripper shank penetrates the material and is pulled through the rock. The installed blade stacks the material onto piles for later loading (Smith 1986).

Ripping and dozing performance fluctuates extremely among different materials as well as within the same rock based upon rock mass structure and rock properties. Key aspects of good performance are operator skills and operating techniques. The applied technique should be adjusted to site requirements such as fines generation, dilution and productivity of the loader unit (Doktan and Scott 1998).

Ripping techniques are listed by Humphrey and Wagner (2011) as:

- Cross ripping / Straight ripping;
- Direction of ripping;
- Spacing between ripper passes;
- Direction of pushing (Front-to-back / Back-to-front / Back-each-pass);
- Uphill / Downhill ripping;
- Ripping depth; and
- Angle of shank.

Every mine site has its own ripping techniques associated to the specific site conditions. Ripping techniques affect productivity, dilution and material sizing including fines generation. At NAC the spacing between ripper passes is usually half a track width (SME 1983). The typical shank angle is 15° past vertical. Other criteria such as ripping direction and ripping depth are highly dependent on job requirements and rock mass properties. Another important factor of dozer efficiency is the pushing distance. As a rule of thumb the pushing distance should not exceed 150 m (Humphrey and Wagner 2011). In some conditions it may be required to pre-blast the rock to achieve efficient dozer production (SME 1983) (Caterpillar 1989).

Following rock-breakage, front-end loaders are the equipment of choice for loading the material onto trucks at NAC. Cat 992G front end-loaders equipped with 12 m<sup>3</sup> buckets are the subject of this study. The combination – dozer and front-end loader – results in reduced breakout force requirements for the loader unit, because the material is already pre-ripped. Thus, front-end loaders provide good performance and offer increased mobility and flexibility as opposed to bigger excavators. This makes front-end loaders favourable especially in multiple thin seam mining operations (Humphrey and Wagner 2011).

### CHALLENGE OF EVALUATION

A challenge lies in comparing a discontinuous CM mining system versus a continuous mining system (i.e. 4200 SM). Reasonable values for a performance evaluation of both mining methods are gathered by reporting upon the complete mining process. It was important to capture data from all mining units allocated to each process. The 4200 SM makes up one WSM-unit, and the dozers plus loaders form the CM-unit. In-the-field data reporting on different levels was the basis of the performance comparison combined with various trial set-ups. A reporting system was developed for analysing production performance of both mining systems. The reporting system resorts to the mine site's internal reporting system. Production rates (IB and coal) are stated in bcm/op.h.

#### Production rate ranges

For comparing productivity of both mining systems, Production Rates (PR) for the mining units were developed. Data analysis of daily PRs and time studies provided the basis for productivity estimation. Additionally, theoretical PR estimations, based on manufacturer information, were performed. Another resource for PR estimation was historical data provided by the mining company. By comparing the results of the productivity estimation approaches and applying mine site specific assumptions, a considerable PR range for each piece of mining equipment (i.e. D11 dozer, 992G loader, 4200 SM) was established. Multiple parameters, such as rock mass properties, mine design and seam thickness, influence PRs. PR ranges were developed to account for different rock conditions and seam thicknesses. The PR ranges provide a guideline for average productivity.

The established PR range for the 992G loader is 550-750 bcm/op.h in IB and 700-850 bcm/op.h in coal. The D11 dozer PR range for ripping and stacking lies between 300-550 bcm/op.h in IB and 450-600 bcm/op.h in coal. The 4200 SM cuts and loads 700-1050 bcm/op.h in IB and 800-1350 bcm/op.h in coal. The identified PR ranges form the basis for further analysis. All calculations were performed considering the different scenarios (low / high PRs) for coal and IB. Figure 2 shows the average PRs of each type of equipment. The ranges are illustrated as error bars.

#### Equipment required

The project target PRs of 700 bcm/op.h in IB and 800 bcm/op.h in coal (i.e. the project KPIs), are the basis for analysis. By dividing the target PRs by the applicable PR ranges identified for each machine, the number of necessary pieces of equipment to achieve target PR was identified, according to Equation 1 and Equation 2. The CM system was considered as one unit. Thus, the amount of machines required for rock-breakage and loading was summed up.

$$\text{Amount of equipment required}_{CM} = \frac{KPI PR}{Dozer PR} + \frac{KPI PR}{Loader PR} \tag{1}$$

$$\text{Amount of equipment required}_{4200 SM} = \frac{KPI PR}{4200 SM PR} \tag{2}$$

This analysis takes different rock conditions and seam thicknesses into account, represented as low and high PRs. The amount of equipment required to fulfil target production is stated in decimal digits. This allows more detailed comparison of the mining systems capacities. The average machinery requirements are reduced by about 70% when using the 4200 SM in comparison to the CM system, as shown in Figure 3.

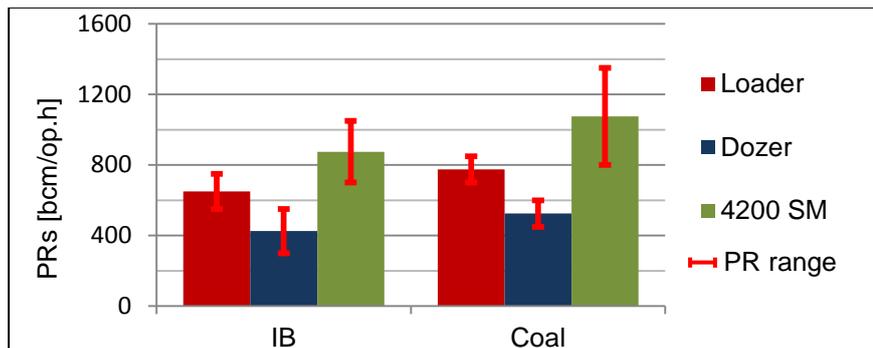


Figure 2: Production rate ranges

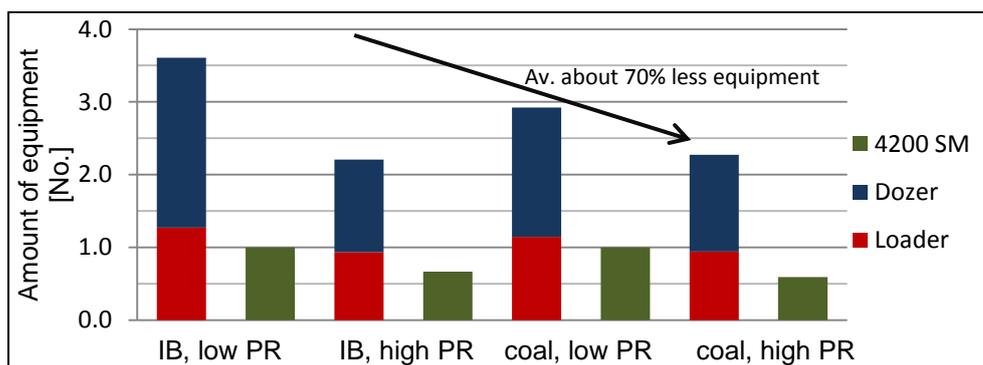


Figure 3: Amount of equipment required

**HEALTH - SAFETY AND ENVIRONMENTAL PERFORMANCE**

The WSM is a new technology at NAC, which involves new potential safety risks. The conveyor system, cutting technology and vertical edges along the cutting lane were amongst new risks identified in risk assessments. Procedures and controls were developed to manage these potential risks.

The reduction in operating units at the working area and working along predefined cutting lanes decrease the risk of collision, which is considered to be one of the main risks of the CM system. The environmental impact assessment revealed better environmental performance of the WSM compared to the CM system. Reduced machinery usage results in less noise emission, dust generation and carbon emissions. Figure 4 shows the fuel consumption of both mining system. The average fuel usage in l/bcm of the WSM is 68% lower than the combined fuel usage of dozers and loaders in the conventional system. Positive effects were also observed in regards to operators' ergonomics.

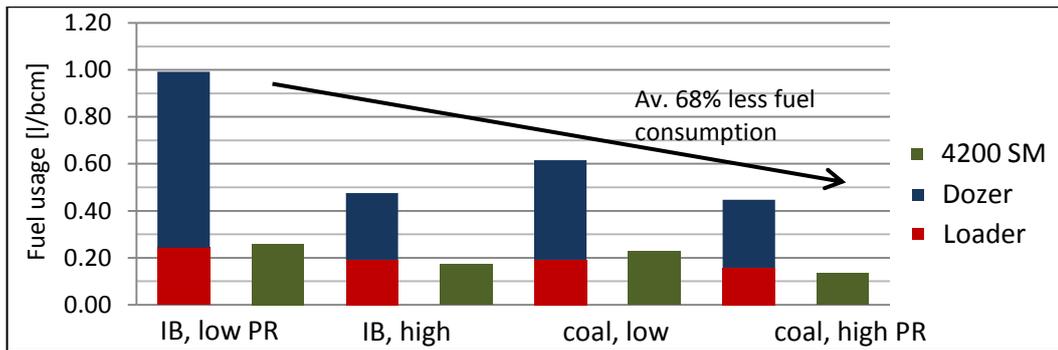


Figure 4: Fuel consumption comparison

**MINING UNIT COST**

Cost savings are a major driver for implementing new technology. Information provided by the mine site, experience from other WSM applications and trial data formed the basis of unit costs analysis. Dozers and loaders were considered as one mining unit. In Figure 5 the unit costs of both mining systems can be seen. The unit costs of the CM system range from about 2.00 - 4.60 AUD/bcm. The 4200 SM operating costs vary between about 0.70 - 1.40 AUD/bcm. The unit cost ranges take the different PR scenarios based on rock properties into consideration. Ownership, maintenance, labour, plant rate, fuel and GET (e.g. picks, ripper boots, and tracks) are included in the unit cost calculation. Overall, an average reduction of about 60% in unit mining costs is achieved by the WSM system.

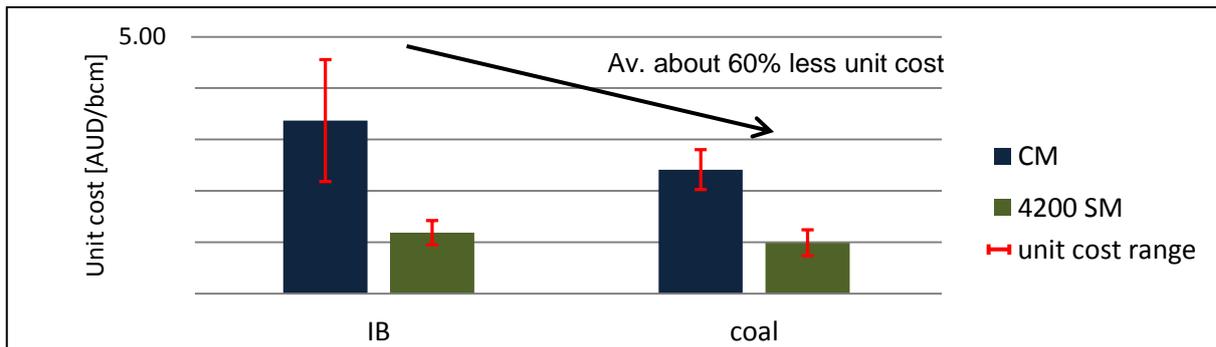


Figure 5: Unit cost comparison

**DEPOSIT RECOVERY**

Selective mining minimises loss and dilution and thereby improves deposit recovery. At NAC, coal and IB can be well differentiated visually (black-white interface). Dozer operators have good skills in mining the different layers separately.

A camera system is installed on the WSM to provide material detection assistance to the operator. Cameras are located behind the cutting drum on the left and right hand side of the drum, sending a high-resolution image stream of the cut floor to the operator cabin. High resolution and colour rendering screens display the floor in the cabin, as shown in Figure 6. Surrounded by a box and fitted with lights and a ventilation system, the cameras are isolated from external factors like dust and sunlight. Similar viewing conditions during day and night are provided. Together with the cutting depth control, this camera system enables highly selective mining. This material detection system works only on a direct-loading WSM.

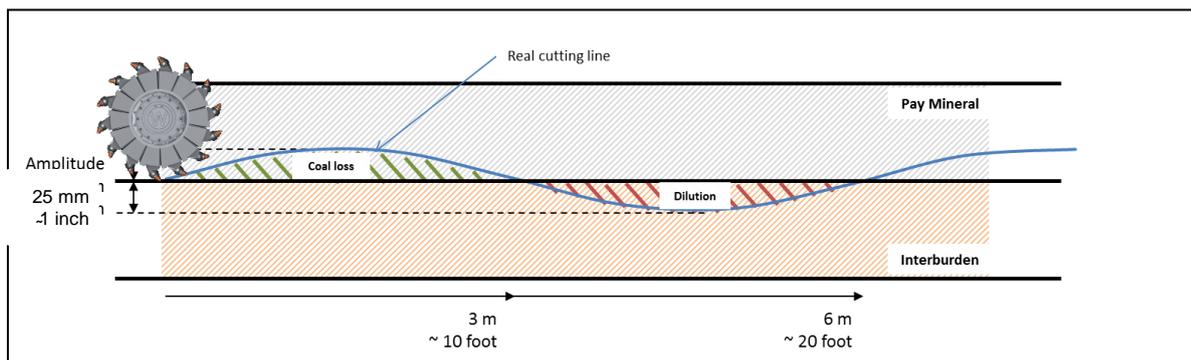
Due to good operator skills, loss and dilution are minimal in both mining systems. Visual observations during the trial period confirmed selective mining practice. Surveying data (i.e. actually mined material) and CHPP yields are regularly cross-checked with the estimated volumes from the mine scheduling

software to identify loss and dilution percentages. This cross-check usually covers a period of 18 months. Since the trial period was limited to four months, this data was only available for the CM system. In lieu thereof, the following theoretical approach was used to estimate loss and dilution of the 4200 SM.



**Figure 6: Material detection camera and screen**

While cutting along the interface between IB and coal, the cutting drum fluctuates around the interface. Wirtgen developed a theory that describes this fluctuation. The fluctuation around the interface can be described as a sine-curve with an amplitude of approximately 25 mm (i.e. 1 inch), as shown in Figure 7. Wirtgen states the amplitude of around  $\pm 25$  mm based on practical experience. Visual inspections as well as operator and supervisor assessments confirm this assumption. The length of the period is assumed to be about 6 m, meaning that the operator corrects the cutting depth 3 m after recognising he is cutting too deep / shallow (Heinrichs 2014).



**Figure 7 – WSM loss and dilution model (Heinrichs 2014)**

Equation 3 describes the sine curve. Based on this sine curve equation and strata information, the percentile recovery can be calculated. This theoretical approach was applied to strata data provided by the mine site. The average loss and dilution are both 3% based on this approach. This indicates better resource recovery and reduced dilution compared to the CM system.

$$y = A \times \sin(bx + t) \quad (3)$$

where

A: Amplitude

b: Period

t: Phase

### IMPACT ON THE COAL HANDLING AND PROCESSING PLANT

The ROM coal properties of both mining systems vary in regards to Particle Size Distribution (PSD), particle shape and dilution. Understanding the impacts of the different mining systems on the CHPP is relevant for the evaluation of the mining systems. The quality comparison was performed on the basis of mine site personnel assessments and a detailed PSD trial. Due to the limited trial period, detailed analysis of CHPP yield and final product quality could not be conducted.

A large scale bulk testing, on-site PSD trial was performed at NAC as part of the 4200 SM trial. The purpose of the PSD trial was to compare the PSD of both mining systems in similar conditions. A large-scale trial was considered to achieve more reliable results for mining applications than standard laboratory methods. The trial setup mainly consisted of a Kleemann Screening Unit MS19D and a Sweco Screening Tower for fine material. The Kleemann MS19D is a mobile screening plant, consisting of a grizzly and a triple deck screening unit (Ranft and Klein 2014). The following sizes were separated by the Kleemann screening plant:

- 150 mm;
- 40-150 mm;
- 16-40 mm;
- 4-16 mm; and
- < 4 mm.

The section finer than 4 mm was further analysed by the Sweco screening tower into:

- 2-4 mm;
- 1-2 mm;
- 0.5-1 mm and
- < 0.5 mm (undersize) (Ranft and Klein, 2014).

Sample sizes were approximately 30 – 40 t. Sample collection in the pit from both mining systems occurred according to the usual loading practice. The location, where the sample was taken, material data, and operational data was recorded. Commissioning was carried out prior to the actual PSD trial to confirm accuracy and correctness of sampling and the process (Ranft and Klein 2014).

Trucks were loaded in the pit and dumped at the trial ROM pad. At the trial area, a small front-end loader fed the coal to the screening plant. Each fraction was weighed after the screening process to derive the PSD of each sample. The PSD trial showed that 60% of the conventionally excavated material met CHPP target particle size requirement (i.e. 2 mm – 38 mm), whereas the WSM produces about 70% of this fraction. The WSM produces 10% more CHPP target particle size. WSM coal contains less over-sized coal and requires less crushing. The PSD trial also indicates that the CM system creates more fines compared to the WSM. The absolute reduction in fines generation is 2.3%. The relative reduction in fines generation compared to the CM system is 15.5%. The PSD curves can be seen in Figure 8 (Ranft and Klein 2014).

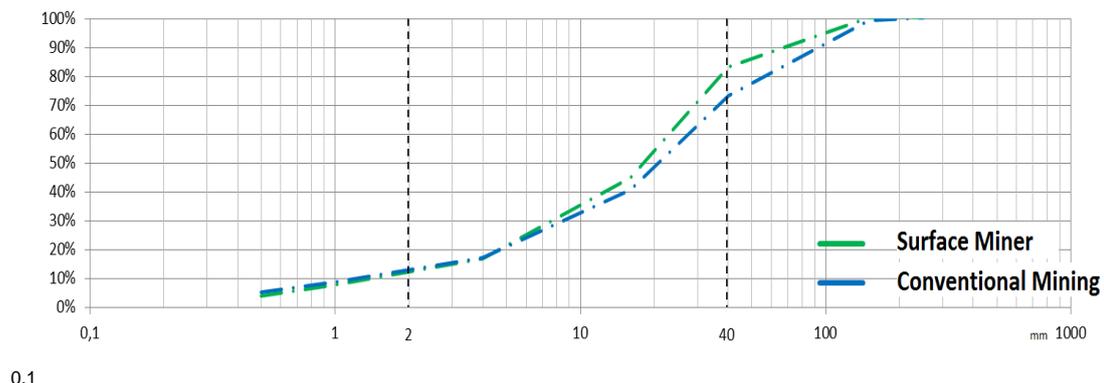


Figure 8: Av. PSD, WSM vs. CM (Ranft and Klein 2014)

Besides PSD, the handling of coal that contains siderite intrusions has a major impact on the CHPP. NAC has two CHPPs with different setups. CHPP1 uses a JIG to separate coarse reject, whereas CHPP2 has only a dry circuit and more crushing is required.

Some coal seams contain lenticular siderite intrusions. Those siderite intrusions cause problems in the CHPP when mined with the conventional dozer-rip operation. The rippers often just scratch the surface

of the siderite or produce oversized material that is unsuitable for the CHPP (+300 mm). Ripping siderite increases wear of the ripper boots and siderite causes bogging and increased wear to the CHPP crushers. Due to the great wear of the CHPP crushers, siderite ROM coal is processed in CHPP1 by preference. However, the high density siderite causes bogging in the JIG and the separation effect decreases. This often results in a breakdown of the CHPP. Therefore, conventional mined siderite coal can only be processed before a planned maintenance shutdown of CHPP1. Consequently, the flexibility to deliver coal of a certain quality at a desired time is limited and scheduling requirements rise.

During the 4200 SM trial period at NAC the performance of the 4200 SM in siderite coal seams was trialled to assess how the 4200 SM handles both – cutting siderite without compromising performance and fragmentation of the siderite. The coal was directly fed to the CHPP. The 4200 SM has proven good cutting performance of both; coal and siderite. There is no significant difference compared to other coal seams. Tool wear remains unchanged. Visual assessment of the ROM and at the CHPP indicates good fragmentation of the siderite. The 4200 SM cuts the siderite down to a particle size smaller than 150 mm, which is more suitable for the CHPPs (McDonald 2014). The 4200 SM siderite coal does not cause any problems at crushers or the JIG. It can be processed at any time at both CHPPs, which increases the flexibility of coal quality management and simplifies mine planning.

### CONCLUSIONS

In summary, it is evident that the 4200 SM has been able to add multiple benefits to the mining process in regards to the numerous objectives at NAC compared to the CM system. The WSM system is associated with higher productivity, thus decreased machinery requirements leading to reduced emissions. Cost savings were identified in unit mining costs and CHPP operating costs. Coal loss and dilution are minimised, resulting in improved deposit recovery. Less machinery interaction on the work area indicates positive safety aspects. The WSM improves ergonomic prerequisites for the operator. Overall the 4200 SM implementation was very successful. All KPIs were fulfilled and often exceeded.

### ACKNOWLEDGEMENTS

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