An investigation into mining coal losses at Klipspruit Colliery

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Abstract

Klipspruit Colliery is experiencing coal losses, which leads to a negative impact on coal production and subsequently loss in revenue. This study aimed to identify the possible causes of coal losses in the No. 4 upper and lower seams. The objectives were to identify potential sources of coal losses through a literature survey, to identify areas where the coal losses occurred, to determine factors affecting coal losses, and to identify the most cost-effective methods to reduce coal losses.

Highwall losses, top-of-coal losses, and coal edge losses were identified as the major areas of coal loss at Klipspruit. These losses were mostly attributed to the drilling and blasting practises of the pre-split, interburden waste, and the coal seams.

Recommendations include re-visiting the current pre-split design and the tolerances adopted for the interburden and coal seam drilling and blasting design. It is furthermore recommended that Klipspruit implement a continuous improvement plan for the drilling and blasting and refresher training for the blasting crew and operators.

Keywords

opencast mining, drilling, blasting, pre-splitting, coal losses

Introduction

South Africa produces approximately 3.3% of the world's coal supply, producing 251 Mt during 2018. The country's coal reserves are estimated at 53 Gt (Eskom, 2019) while coal sales for 2018 were R139.4 billion (Mining for Schools, 2018). The Witbank and Highveld coalfields are the major sources of coal, contributing 75% of the country's coal production. South Africa produces mainly thermal coal, which generates some 90% of the country's electricity. The coal mining industry is the third largest employer in South Africa's mining sector. In 2018, some 86 000 people were employed, which represented about 19% of the total workforce in the mining industry (Minerals Council South Africa, 2019; Mining for Schools, 2018).

It is estimated that the global coal industry loses about US$480 million (R5.5 billion) annually in revenue during the mining process (Baruya, 2012). Losses occur in various areas of the supply chain. including mining, during storage and transport, coal separation, and beneficiation. This study focuses primarily on coal losses during mining.

According to Goswami, Brent, and Hain (2008), the Australian coal mines experience 5% to 25% in-situ coal losses, which are usually blast-induced. It is estimated that a 1% improvement in coal recovery would lead to revenue increases of between A$1 million and 3 million per annum.

Coal loss mechanisms

Coal losses experienced during mining can be classified in several categories, discussed below.

Geological and geotechnical losses

These are naturally occurring losses that cannot be prevented and occur due to geological structures such as dykes and faults that were not identified during the exploration stage (Malambule and Zvarivadza, 2017; Ngwenyama, 2017).

Highwall losses

Highwall coal losses are caused by underbreak of the highwall. Potentially, these can be recovered during mining of the following strip, although this is not common practice.

Low wall losses

During blasting of the overlying rock, the rock ‘swells’, increasing the volume in the spoil. Due to the limited space to pack the material it is common for low wall slope failures, or sloughing, to occur, covering some of the coal. These losses may increase with an increase in the overlying rock mass. The recovery of low wall coal losses is generally unadvisable for reasons of safety (Ngwenyama, de Graaf, and Preis, 2017).

Top-of-seam losses / scalping

Scalping occurs during exposure of the coal seam, when the dragline, shovels, or dozers remove some of the coal. The coal seam may be damaged during blasting of the overlying waste rock. (Goswami and Brent, 2016). The excessive energy fractures the top of coal, which may lead to scalping. Further losses may occur due to poor operator skills, and these losses may increase during the night shift as it becomes difficult for the operator to distinguish between the waste material and the coal. The rate at which the coal is lost is also dependent on the friability of the coal (Ngwenyama, de Graaf, and Preis, 2017).

Floor losses

These are losses due to coal being left on the pit floor during loading or excavation, and are relatively low. They are highly dependent on the skills of the operator i.e. the ability of the operator to remove all the coal. An accumulation of water on the floor or loading during periods of [oor visibility may increase floor losses (Ngwenyama, de Graaf, and Preis, 2017).

Spontaneous combustion

Spontaneous combustion occurs when in-situ coal is exposed to oxygen and heats up until it ignites (Phillips, Uludag, and Chabedi, 2011). This decreases both the quantity and quality of the coal. Spontaneous combustion can also occur on stockpiles. increasing coal losses (Phillips et al., 2003)

S Project background

Klipspruit Colliery is situated in Mpumalanga Province, close to Ogies. A dragline is used in the main pit to expose the coal seams, and a truck and shovel operation exposes the coal seams in the mini-pit. During June 2017, the mine’s coal reserves were estimated at 22 Mt. The majority of the coal produced is thermal coal, which is exported. The stratigraphy consists of six coal seams in the mining area, namely: 5 seam (S5), 4 upper seam (S4U), 4 lower seam (S4L), 3 seam (S3), 2 seam (S2), and 1 seam (S1). The S3 is considered uneconomical due to its low thickness and therefore is not mined.

The mine has been experiencing coal losses for several years. Although the sources of such coal losses are known, the need to identify and address the root causes needs to be addressed.

In addition to a literature review, site visits for data collection and interviews were conducted to determine areas in which major coal losses had ocurred.

Current coal loss evaluation methods at Klipspruit Colliery

The resource and reserve models are used to calculate the volumes of coal available for extraction. Wire-line logging is used to determine available coal for mining and the results are compared to the actual coal mined. A difference between the theoretical calculations and the actual mined coal indicates possible coal losses.

Coal losses at Klipspruit Colliery

The study was conducted between ramp 3 and ramp 4 in the main pit. In this area the S5 and S1 seams were not mined. The coal losses recorded include top-of-coal losses, coal in floor losses, low wall or highwall losses, and geological losses as shown in Figure 1.

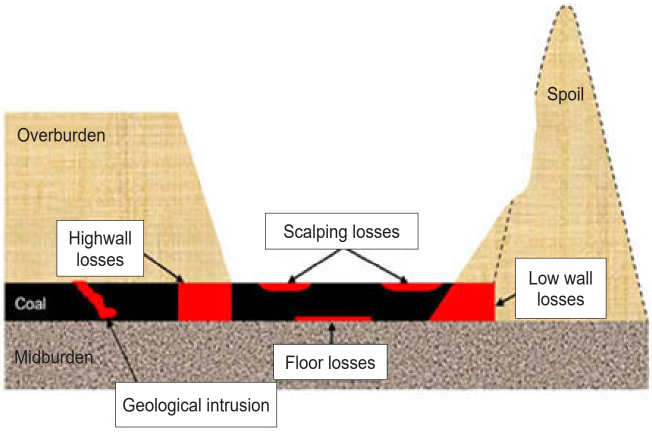

Figure 1—Types of coal losses experienced at Klipspruit Colliery

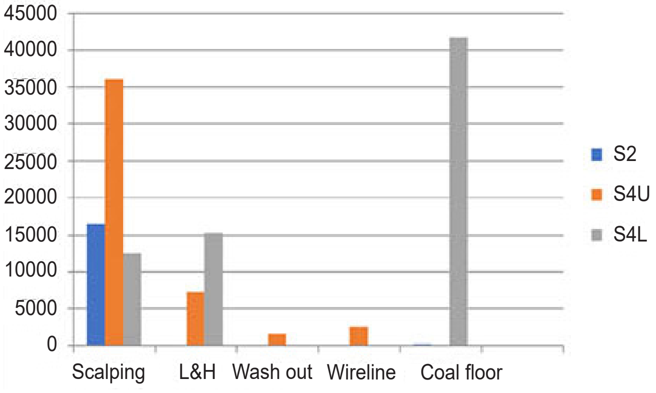

Figure 2—Coal losses on different seams

The S4L seam was the largest contributor to the coal losses that occurred during 2018, as shown in Figure 2.

Current controls for coal losses

Control of coal losses is divided into three operational sections, namely exposure, drill and blast, and extraction. Each of these sections implements its own control measures as stipulated by the mine’s standard operating procedure (SOP).

Problem statement

Klipspruit Colliery is currently experiencing coal losses. which have a negative impact on the profits generated by the mine. This study aims to identify the possible causes of coal losses and suggest practical ways to reduce these.

Methodology

In order to acquire sufficient data, the following steps were taken.

- ➤ An extensive literature review was conducted to understand possible coal losses and how they can occur, and to examine the different sources of coal losses at various collieries and how the mines deal with the problem.
- ➤ Site visits to Klipspruit Colliery were undertaken for data collection to determine areas which have experienced major coal losses.
- ➤ Mining personnel were interviewed to gain a better understanding of the coal losses at Klipspruit Colliery.

Results and analysis

The major coal losses experienced at Klipspruit Colliery are grouped into three main types:

- Highwall
- Top-of-coal
- Coal edge.

To address the abovementioned coal losses the following blasting method designs will be discussed in more detail.

Pre-split design

Highwall losses are due to sub-standard blasting results, typically perimeter control. When the block being blasted is not broken to the planned perimeter, the 'frozen' material on the highwall, if not removed by the dragline, will result in coal being lost. Perimeter control can be an effective way to eliminate the coal losses.

Current pre-split design

The overburden on S4U is pre-split blasted before the main production holes are drilled, charged, and blasted.. The current pre-split parameters are listed in Table I. The current design was assessed based on industry standards. A typical block at the Klipspruit Colliery is 100 m long and 50 m wide. Pre-split holes are drilled through the coal seam.

Table I

Current pre-split parameters

Spacing	3 m
Hole diameter	256 mm
Mass of explosives	2.0 kg/m
Average depth	25 m
Pre-split bag diameter	250 mm
Explosive	HEF 100 (booster- sensitive bulk emulsion)
Booster	400 g
Initiation system	Detonating cord

Table II

Splitting factors for different rock types (University of Pretoria, 2018)

Rock properties	Splitting factor (kg/m^2)
Brittle, low density	0.2–0.4
Hard, high density	0.3–0.6
Competent sedimentary	0.4–0.7

The current pre-split design was assessed based on the following criteria (de Graaf, 2018):

$$M_H = S \times P$$

where

M_H = Mass per metre in the hole (kg/m)
S = Spacing (m) (15– 20 hole diameters)
P = Splitting factor (kg/m^2)

The splitting factor depends on the rock mass properties and is indicated in Table II

Evaluation of pre-split design using current diameter holes

Using the factors in Table II, for a hole diameter of 256 mm, the spacing is expected to be between 3.84 m and 5.15 m. The current mine design has a spacing of 3 m, which falls outside the recommended range.

The overburden on the mine is a competent sedimentary rock;. According to Table II, the splitting factor ranges between 0.4 and 0.7 kg/m2. For this study and at Klipspruit Colliery, a splitting factor of 0.5 kg/m2 is used. Taking into consideration the minimum and maximum values for spacing, the acceptable range for mass of explosive per metre is calculated as follows:

$$M_{Hmin} = 3.84 \times 0.5 = 1.92 \text{ kg/m}$$
$$M_{Hmax} = 5.15 \times 0.5 = 2.58 \text{ kg/m}$$

The current mass of explosive per metre, 2 kg/m, is well within the acceptable range. However, the spacing falls outside the guidelines, which could result in uneven splitting of the highwall and potentially lead to both under- and over-break of the highwall. While there is no universally accepted hole diameter for pre-split blasting, industry practices suggest that smaller diameter holes in conjunction with smaller spacing may yield improved results.

Half cast factor

Half cast factor (HCF) is a practical in-field method used to assess the success of the exposed pre-split. A well-blasted pre-split will show half barrels in the highwall. The HCF is represented as the sum of the total length of visible half barrels to the total length of holes drilled. HCF calculation is based on Figure 3, which shows a 25 m highwall with visible barrels. Nine barrels of 25 m are expected. The HCF was calculated as 23%, which is relatively low.

Proposed pre-split design

In addition to the current drill bit diameter (256 mm), there are two smaller diameters available; namely 141 mm and 200 mm. Two pre-split scenarios were designed using these two bits, as shown in Table III. Scenario 1 is the pre-split design using a 141mm bit, and scenario 2 is the design using a 200 mm bit. Parameters for both scenarios are shown in Table IV.

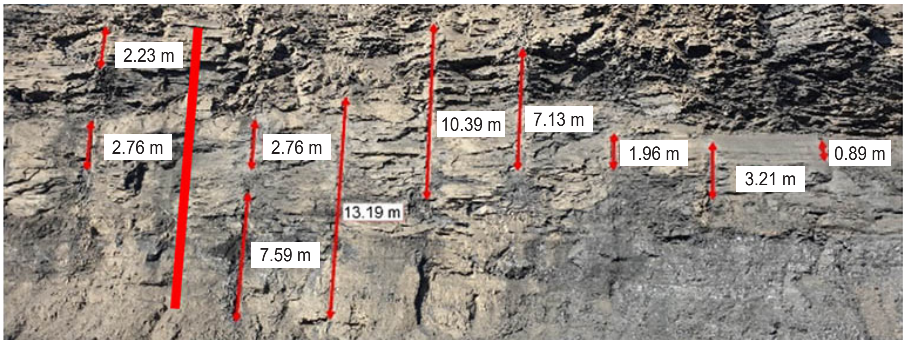

Figure 3—Highwall showing length of half barrels (South32, 201)

Table III

Pre-split design for 141 mm and 200 mm hole diameters

Parameter	Scenario 1	Scenario 2
Hole diameter (mm)	141	200
Spacing (m)	2.5	3.5
Splitting factor (kg/m^2)	0.5	0.5
Mass of explosives (kg/m)	1.00–1.41	1.5–2.00

Table IV

Number of holes drilled for 141 mm and 200 mm hole diameters

Hole Diameter	Holes drilled for one block	Difference from current (%)
Scenario 1 (141 mm)	40	17.6
Scenario 2 (200 mm)	29	-14.7

A pre-split with 141 mm hole diameter is expected to yield cleaner splitting; however, it will result in more holes drilled due to smaller spacing. For a block that is 100 m long, 34 holes need to be drilled for the current pre-split design. The number of holes that need to be drilled for hole diameters of 141 mm and 200 mm are shown in Table IV.

According to Table IV, scenario 1 may increase the number of holes required for a pre-split by up to 18%. Scenario 2, on the other hand, may reduce the total number of holes by up to 15%. Both scenarios are expected to reduce highwall coal losses. Scenario 2 is the most feasible of the two as it presents an opportunity to reduce the number of holes drilled, thus, reducing both drilling and blasting costs of the S4U overburden.

Overburden and parting drilling and blasting

Drilling plays a pivotal role in the success of the blasting outcome, and subsequently has an impact on the top-of-coal and edge losses when the burden is blasted. This is especially true at Klipspruit because the burden (overburden and parting) is drilled to top of coal. In this section, we consider different methods to determine the most suitable ways to minimize coal losses from the drill and blast for exposure perspective.

Current blast parameters

Top-of-coal damage and losses are normally attributed to overcharging of the overburden. The overburden is drilled and blasted to expose the S4U. When S4U extraction is compete, the parting is drilled and blasted and the S4L extracted. The overburden consists mainly of gritty sandstone with subordinate shale and has an average thickness of 25 m. The parting, on the other hand, is composed mainly of sandstone and has an average thickness of 1.8 m. The blasting parameters used for both overburden and parting are listed in Table V.

The overburden blast layout provides satisfactory results in terms of fragmentation.

Evaluation of current parting drill and blast pattern

According to Table V, a planned powder factor of 0.45 kg/m^3 is well within the industry accepted range of 0.35–0.65 kg/m^3 for sandstone. From a design perspective, the blast design is expected to yield satisfactory results. However, when the powder factor was calculated using the blasting parameters in Table V, a higher powder factor was obtained – 0.8 kg/m^3 compared to the planned powder factor of 0.45 kg/m^3. The calculated powder factor falls out of the recommended range of 0.35–0.65 kg/m^3. The current drill and blast parameters do not meet the required powder factor. A high powder factor implies that a blast-hole may be under-burdened, thus resulting in some energy directed into the coal seam.

Table V

Current drill and blast parameters for parting and overburden

	Parting	Overburden
Pattern ($B \times S$)	4 × 4 m	7 × 8 m
Block size	100 × 50 m	100 × 50 m
Hole diameter *(D)*	141 mm	256 mm
Height *(H)*	1.8 m	25 m
Explosive density *(ρ)*	1.15 g/cm^3	1.20 g/cm^3
Stemming *(T)*	0.5 m	6 m
Mass charge per metre *(Mc)*	17.7 kg/m	60 kg/m
Planned powder factor *(Pf)*	0.45 kg/m^3	0.84 kg/m^3

The burden and spacing were also calculated using the planned powder factor of 0.45 kg/m^3 and current hole diameter of 141 mm. The burden and spacing were calculated as 5.5 m. However, the burden is now significantly more than the parting width. This will result in poor fragmentation and increased top-of-coal losses. To maintain the powder factor the burden and spacing, as well as the blast-hole diameter, should be reduced.

Drill and blast pattern to match parting thickness

Apart from matching the powder factor to the type of rock being blasted, the hole diameter and the bench height ratios needed to be addressed. The height *(H)* and hole diameter *(D)* are related according to the following equation (AEL Mining Services, 2014):

$$H \geq \frac{D\ (\text{mm})}{15}$$

By rearranging the above equation, the maximum hole diameter that is most suited for a 1.8 m parting was determined as

$D \leq 27$ mm

The mine is currently using a hole diameter of 141 mm, which is approximately five times greater than the recommended diameter. The mass of explosives per metre changes from 17.7 kg/m to 0.7 kg/m. To maintain the current powder factor, the burden and spacing were calculated as 1 m × 1 m. The tight spacing and burden have serious implications in terms of practicality, time, and costs. This pattern could result in lower coal losses; however, unintended consequences need to be investigated.

Due to equipment constraints, the smallest drill bit the mine has is a 102 mm diameter. The powder factor is maintained at 0.45 kg/m^3, and the spacing-to-burden ratio is changed to 1.15 for better distribution of explosive energy. Table VI shows the blast design to be used in the interim.

Coal losses due to drilling to top of coal

As mentioned previously, both parting and overburden are drilled to top of coal. This may lead to pulverization of top of coal during blasting. The direct contact between the explosive column and top

Table VI

Interim blast parameters to minimize top-of-coal losses

Parameter	Value
D	102 mm
Mc	9.4 kg/m
T	0.5 m
A	1.15
L	1.3 m
B	3.5 m
S	4 m

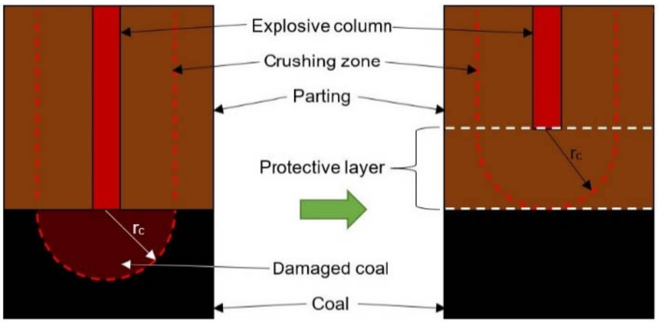

Figure 4—Proposed design with protective layer

of coal implies that a fraction of the explosive energy goes into the coal seam. The energy in the crushing zone breaks coal into fine particles which are not recoverable (Esen, Onederra, and Bilgin, 2003).

According to Esen, Onederra, and Bilgin (2003) there is a relationship between the blast-hole radius (r_o) and the radius of the crushed zone (r_c). There are many models that attempt to quantify the crushing zone of an explosive column, and they all suggest that the ratio, r_c/r_o, does not exceed 3 to 5 blast-hole radii (Esen, Onederra, and Bilgin, 2003). Assuming that the r_c/r_o ratio holds true not only laterally, but also vertically at the toe of the blast-hole; potential coal losses can be calculated.

To determine the potential top-of-coal losses that occur due to drilling to top of coal, assuming that there is no over-drilling, an approach by Esen,

Onederra, and Bilgin {2003) was used. The extent of the damage into the coal seam is shown in Table VII.

Due to drilling to top of coal, damage to top of coal may extend an average of 512 mm and 282 mm into the S4U and S4L, respectively. Thus as much as 18% of both the S4U and S4L seam thicknesses may be lost. It is worth noting that the true extent of the damage is dependent on more than the hole radius.

Table VII

Extent of coal losses due to drilling to top of coal

	S4U	S4L
Depth ofdamage (mm)	512	282
Seam thickness (m)	2.82	1.57
Potential loss in relation to seam thickness (%)	18	18

Since the extent of possible coal loss has been determined, controls which include leaving a protective layer on top of the coal, as seen in Figure 4 should be put in place to minimize coal losses due to drilling to top of coal.

Coal losses due to drilling tolerances

Inasmuch as strict adherence to the plan is encouraged, getting the correct depth to the last millimetre can prove time-consuming and almost impossible in practise. Hence the mine developed a standard to allow for some variation. Currently, drilling is done to a tolerance of ±1 m, meaning a blast-hole that is either 1 m shorter or longer than the planned depth is considered acceptable. Blast-holes that are more than 1 m off the planned depth are re-drilled. It was found that on average 50% of the holes are not drilled to their planned depth but are still within the 1 m tolerance. Of that 50%, some 62% of the holes are drilled longer than the planned depth. Evaluating the drill-hole data, over-drilling of blast-holes is on average 57 cm.

Parting

S4L coal is extracted after removing the parting layer overlying the S4L. The S4L has a maximum thickness of 5.17 m, with an average thickness of 1.57 m. Using the drill pattern in Table V, the number of holes drilled for one block was calculated at 313 holes. equating to 0.03 holes per BCM. The number of holes that are drilled beyond the planned depth but are still within the 1 m tolerance was calculated as 0.01 holes per BCM.

A small deviation from the planned depth can have an effect on the quantity of coal mined. Over-drilling by 0.57 m on the 4 × 4 m pattern, taking into account the number of holes that are over-drilled, results in an estimated coal loss of 1327 t, approximately 11.3% coal loss per block.

Overburden

S4U coal is extracted after the overburden has been removed. The S4U has a maximum thickness of 5.53 m, with an average thickness of 2.82 m. The overburden drill pattern and the block size shown in Table VI indicates 89 holes drilled per block.

The number of holes that are drilled beyond the planned depth but within the 1 m tolerance is 28. Using the 7 × 8 m pattern and the number of holes that are over-drilled,; the estimated coal lost is 1340 t.

The expected S4U coal tonnage is 21 150 t per block. However, as much as 5.9% of that tonnage is lost due to non-adherance to drilling tolerances.

Reduction of drilling tolerances

From the above calculations, drilling tolerances have a considerable influence on the coal losses at Klipspruit Colliery. The tolerance should be reduced to minimize drilling into coal during parting blasting. A methodical approach was followed where the tolerance was reduced in steps of 25%, as shown in Table VIII. The analysis suggests that the holes are over-drilled by 57% (0.57/1) of the tolerance.

Table VIII

Effect of reduction of drilling tolerance

Tolerance (m)	0.75	0.5	0.25
Potential length drilled into coal (cm)	42.75	28.50	14.25
Potential change in coal loss (%)	−25	−50	−75

Discussion

Highwall coal losses

The highwall coal losses are a result of underperforming perimeter control. The overburden pre-split is currently drilled with a 256 mm hole diameter. Due to unsatisfactory results and a low HCF. two hole diameters were compared to the current pre-split design.

Improved perimeter control

The reduced spacing and smaller diameter drill-hole has been shown to yield better results than the current design. This is due to improved control of the explosive energy during pre-split blasting. Thus, 141 mm is the preferred hole diameter for pre-split drilling.

Practicality

The pre-split design should be as practical as possible. This includes the time and effort taken to prepare, drill, charge, and blast. Practicality is assessed in terms of the area covered by each hole drilled. The greater this area, the easier and quicker it is to blast the overburden pre-split. (Table IX).

According to Table IX, scenario 1 is more practical as regards the amount of drilling required. For every hole drilled, scenario 1 covers 17% more area than the current design due to the greater spacing between the pre-split holes. Scenario 2, on the other hand, covers 17% less than the current design due the smaller spacing.

Costs

The aim is to reduce coal losses while reducing the operating costs. The pre-split parameters across the pre-split designs are similar. The mass of emulsion per hole varies for each design; however, the overall mass per unit area does not change, due the chosen splitting factor of 0.5 kg/m2.

Using the areas covered per hole and the unit costs respectively; the costs for the current design, scenario 1, and scenario 2 were calculated. Table X shows the cost comparison of the three designs.

From the cost perspective, scenario 1 is the most suitable design to mitigate overburden highwall losses, as it is the most financially feasible of the three designs.

Top-of-coal losses

Two possible solutions were identified to address top-of-coal losses: changing the current blasting pattern and avoiding drilling to top of coal. The overburden blasting pattern is performing as expected. Due to the parting thickness of 1.8 m, only a few drill and blast options are available for the parting.

Table IX

Area covered per hole

	Current design	Scenario 1	Scenario 2
Hole diameter	256 mm	200 mm	141 mm
Area covered per hole	75 m^2	87.5 m^2	62.5 m^2

Table X

Cost comparison (rands per m2)

Cost item	Current	Scenario 1	Scenario 2
Drilling	47.80	41.00	52.40
Initiation	2.00	1.70	2.40
Bulk emulsion	3.15	3.15	3.15
Overall costs	52.95	45.85	57.95

Table XI

Hole distribution

	Parting blasting design	
	Current	Recommended
Pattern (m × m)	4 × 4	1 × 1
Holes per BCM	0.03	0.6

Changing the current blasting pattern

From the results, it is evident that a suboptimal hole diameter is a possible cause for high top-of-coal losses, particularly when drilling and blasting the parting. It is expected that a hole diameter of 27 mm will result in less coal losses due to better distribution of explosive energy across the block. The current design has a lower distribution of holes compared to the recommended design, as shown in Table XI.

The hole distribution shown in Table XI implies that for every 100 BCM's, there are approximately three holes drilled for the current parting design compared to 60 holes for the recommended hole diameter of 27 mm.

The new pattern has the potential to decrease the number of holes drilled per block while reducing the damage to top of coal, thus reducing the overall costs for drilling and blasting. The two patterns are similar, the only difference is the number of holes that need to be drilled per block.

The costs of drilling and emulsion using the current pattern are R129 per metre and R6.30 per kilogram respectively. The current and two other drill and blast designs were compared. It was determined that the drilling costs for a 27 mm blast-hole are 16 times more than the current drilling costs. Such costs are not justifiable as the costs outweigh the possible revenue generated from recovering the coal that would have been damaged. The drilling costs for the 102 mm hole diameter are 15% higher than for a 141 mm hole – R9.21 per cubic metre compared with R8.00 per cubic metre. However, the higher drilling costs are offset by lower emulsion costs per BCM. More work is required to determine the ideal hole diameter for parting blasting. In the interim, the mine should make use of the 102 mm hole diameter to minimize the top-of-coal losses. In addition to reducing coal losses, changing the blast pattern has the following advantages:

- ➤ Less explosive energy penetrating top of coal
- ➤ Easy to implement (no additional training required)
- ➤ No additional resources required to be assigned
- ➤ Improved floor control.

Drilling tolerances

Coal losses related to drilling tolerance constitute approximately 11% of the total losses. Three possible tolerances were considered: 75 cm, 50 cm, and 25 cm. Reducing the tolerance to 50 cm could potentially reduce the losses due to drilling to top of coal by 50%. This will also promote accurate drilling by the operator.

Conclusions

Coal losses are a complex problem by nature. The major areas of

Table XII

Coal loss types and causes at Klipspruit Colliery

Category	Potential causes
Highwall losses	Poor perimeter control during blasting Suboptimal pre-split design.
Top-of-coal losses	Drilling to top of coal Error between planned and actual powder factors Drilling tolerances
Coal edge losses	Movement of coal seam during throw blasting

coal loss at Klipspruit Colliery and their causes have been identified and possible solutions proposed.

Coal losses at Klipspruit can be grouped into highwall, top-of-coal, and edge losses. For each of these the root causes are listed in Table XII.

All these losses are largely related to blasting practices and loading of overburden above the S4U and S4L. Some of the contributing factors include drilling accuracy, prime mover operator skills, rock properties.- and the underlying geology.

Recommendations

Klipspruit Colliery should institute a continuous improvement plan for their drilling and blasting practises by analysing blasts to identify improvement opportunities. Furthermore, the blasting crew and operators should attend refresher courses to ensure that they comply with the SOPs at all times. This will also improve employees‘ understanding of the need to comply with SOPs (such as drilling to the correct depth) and the adverse impact of non-compliance on coal recovery.

Recommendations to reduce/minimize the different types of coal losses at Klipspruit Colliery are as follows:

Highwall losses

- Changes to the current pre-split design should be made to ensure that the planned highwall perimeter is always achieved during blasting.
- A smaller hole diameter for the pre-split design should be considered for the overburden.

Top-of-coal losses

- The mine should avoid drilling into the coal seam by implementing strict field controls. When holes are over-drilled, corrective measures should be implemented such as backfilling. However, if the blast-hole is drilled to the coal seam coal losses are inevitable due to blast damage. A 30 cm protective layer should be left above the seam to reduce blast damage to the top of the coal seam.
- Drilling tolerances should be reduced from 1 m to 0.5 m to encourage more accurate drilling, which will reduce coal damage and losses.

Coal edge losses

- The recommended change in the blast design to address top-of-coal losses is expected to also limit seam movement, thus reducing coal edge losses.

Suggestions for further work

The results of the study could be verified using a larger area of the mine. This could be followed by an investigation into coal losses on the other seams (S1, S2, and S5).

The drilling and blasting tolerances currently used at Klipspruit Colliery should be further investigated. Losses experienced in other areas of the coal supply chain at the mine, such as during beneficiation, should also be investigated.

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