Managing Coal Loss Using Blast Models and Field Measurement

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ABSTRACT
Coal loss is an important issue at many coalmines, with losses of five per cent being common. The type of loss varies from mine to mine but is dependent on mine strata, the drilling and blasting processes applied and the mining method used. Typical coal loss mechanisms from the drill and blast process are coal roof damage and edge loss. Usually a reduction in coal loss is in direct competition with the need to provide material that is well-fragmented and a muck pile that has the required cast percentage. These competing issues were addressed over a two-year period at a mine in the New South Wales Coalfields by implementing a five-step approach. This was centred around building an understanding of the coal loss mechanisms utilising proprietary heave-modelling software, measuring coal losses by comparing survey to drill and/or gamma logs and implementing appropriate coal loss reduction processes. The end result exceeded expectations with a 95 per cent reduction in coal loss. Mine excavation productivity was maintained and coal loss minimised to less than one per cent of the in situ coal block.

INTRODUCTION
In recent years there has been a great deal of discussion within the coal mining industry on methods to minimise coal damage. In both New South Wales (NSW) and Queensland coalmines a number of methods have been employed to minimise the coal damage caused by the drill and blast portion of the mining process with varying degrees of success. A coal loss reduction program can be in competition with other factors such as cast percentage and centre of mass movement that are also required to be delivered by the drill and blast teams. Over a period of two years a number of methods of managing coal loss whilst maintaining mine productivity and controlling operating cost were trialled at a mine in the NSW coalfields. To achieve the required end goal the following five-step process was employed:

1. develop a baseline of the coal loss occurring and the mechanisms causing this
2. implement a quality assurance / quality control (QA/QC) system targeting drill hole and coal stand-off accuracy
3. model the coal loss mechanism resulting in the loss
4. develop a coal loss reduction program from this work
5. implement the program with the simple systems being carried out first, building up complexity as site capability develops.

STEP 1 – COAL LOSS BASELINE
Figures 1 and 2 show the top of coal at the start of the coal loss management program. As can be seen the top of coal had a number of zones of damage where rock had been punched into the coal roof. To determine the reasons for the coal damage a review of the drill and loading records was carried out with the following conclusions:
• the location of the coal roof damage zones predominantly correlated with the location of blastholes that, according to the drill records, had ‘touched coal’
• a review of the backfill process employed showed that there were inconsistencies in the type of material used (drill cuttings or stemming gravel)
• there was considerable uncertainty around the true stand-off of explosives to the top of coal.
Therefore a QA/QC process was required as the next step in the program before considering more complex solutions.

STEP 2 – IMPLEMENT A QUALITY ASSURANCE PROCESS
As mentioned in Step 1, the visible overburden material in the coal roof indicated that the coal was being damaged by insufficient and/or ineffective stand-off due to poor backfilling material. To achieve the required result the following a QA/QC system was implemented:
• touch coal holes were drilled as per the previous process
• touch coal holes were gamma logged to ensure the touch coal drill depth was correct and this feedback was provided to the drillers
• coal depth data was used to update the coal model, specifically the top of coal surface
• the touch coal hole information was used to develop the required drill hole depth and load sheets for each blasthole for the remainder of the blast
• the remainder of the shot was drilled
• all backfilling was to be carried out using gravel
• backfilling was only to be done under the supervision of the blast crew using individual load sheets developed by the drill and blast engineer
• redrilling of blastholes holes was carried out when holes were not within 1 m of the required depth
• the load sheets were filled out for actual depth, explosive quantity and type loaded and final stem height
• all variations greater than 1 m were noted and the drill-and-blast engineer informed for reporting and measuring continuous improvement.

Post implementation of the QA/QC process, the coal damage on the roof of the coal met the mine requirements whilst the coal edge losses as shown in Figure 3 were not satisfactory and needed further analysis.

Based on survey and visual inspection, the amount of edge coal loss was approximately 11.5 per cent of total coal volume. The damaged coal in the lower section of the seam was estimated as a further two per cent of the coal volume. The mine had a wash plant, so this damaged coal was recovered but required washing. This was an added cost as the undamaged coal seam met coal customer requirements without washing. Therefore, there was a total of 13.5 per cent of coal that had been affected by the drill and blast process.

STEP 3 – MODELLING THE COAL LOSS MECHANISM

To determine the reasons for the coal edge damage a set of blast designs were simulated using a proprietary heave model (SoH). The heave model uses a finite/discrete element numerical engine. To model the heave process for a bench blast, a vertical two-dimensional section is taken through the bench. The section of bench that contains the blast is defined as the ‘blast domain’ and is filled with rectangular particles that are tightly tiled. These discrete particles are fully deformable finite elements that support stress and strain, so when set face-to-face they support stress waves. Zones or regions of different rock types can be applied to the blast domain. Blastholes are overlaid on the particles, based on the blast design, and pressure loads are applied to the relevant faces of the particles that surround the blastholes. The pressure loads are obtained from the proprietary non-ideal detonation code CPeX (Dare-Bryan, Byers and Theobald, 2010; Dare-Bryan, Pugnale and Brown, 2012). The inputs into the model are the geological parameters (as detailed in Table 1), survey section for the preblast bench, face, void and coal roof, and the blast design. Figure 4 illustrates the pit parameters with the ‘blast domain’ is the red region set in the bench. The light blue are the coal seams with the yellow the interburden and partings.

Figure 5 shows the baseline modelling result. The modelling identified that the primary damage to coal edge was due to the movement of the rock into the void shearing the front edge of the coal seam roof. The void depth varied along the strip from 12 m to 18 m. As shown in Figure 5 the initial damage occurring around the base of the blasthole was creating a weakness in the coal seam that was then being moved by the moving rock mass of the blast. The damage continued for
up to five rows from the free face. The coal dip varied along
the strip and had an influence on the amount of coal loss.
The modelling identified that the movement of material into
the void and the depth of the void was of greatest influence.

**STEP 4 – SYSTEMS TO REDUCE COAL LOSS**

After the review of the coal damage mechanism via the
baseline modelling, the existing blast management techniques
and the SoH modelling work it was concluded that the most
suitable options for reducing coal loss were the use of:

- ‘baby’ decks
- the Stratablast™ methodology

The heave models showed that there would be a reduction
in coal edge loss by both methods. In the review it was
acknowledged that options such as buffering of coal edge
before blasting and other drill and blast processes such as
‘dynamic buffering were not suitable. Coal edge buffering was
not possible due to operational requirement of a blast in this
horizon soon after the excavation of coal due to the operational
need to continue dozer push in this region to maintain a low-
cost mining methodology and drill and blast processes such
as ‘dynamic buffering’ were not possible due to geological
and environmental factors that historically have been an issue.
In all cases electronic initiation systems have been used to
ensure optimum timing was implemented. The aim of this
process is to minimise the complexity of processes in the drill
and blast process whilst delivering the required coal loss
reduction, maintaining the mining schedule and minimising
the need for changes in the other mining processes.

**STEP 5 – COAL LOSS IMPLEMENTATION**

**Baby deck system**

As mentioned earlier, the process was to minimise drill
and blast complexity whilst delivering the required result.
Therefore, the baby deck system was employed as the next
step in reducing coal loss. In baby deck cast blasting, a separate
toe charge distances the main column of explosive from the
coal seam underneath. The initial timing delay between decks
was 100 ms. The loading profile as shown in Figure 6 and the
modelling result in Figure 7. The actual loading regime and
location of the inter deck was varied with the dip of the coal
to reduce the risk of the shearing of the coal edge from the
material moving into the void.

A survey of the coal roof after the removal of the
overburden was taken with examples shown in Figures
8 and 9. Overall the coal loss was reduced by one third to
8.5 per cent over a strip length (incorporating five blasts).
A number of baby deck timing delays were used with delays
up to 600 ms, up to five rows of baby decks and in each
case the baby deck was fired after the main charge. The coal
loss results showed that there was little difference between
the various baby deck options considered. The ‘baby deck’
loading and timing program achieved a 33 per cent reduction
in coal loss to 8.5 per cent compared to the standard design.
This confirmed the modelling work that showed that there would be some reduction in coal loss but the main issue that required to be dealt with was the movement of material into the void that was causing the coal edge to move.

**Stratablast™**

The next step was to apply the Stratablast methodology to test the modelling results that showed that this method could deliver a large reduction in coal loss. The technology employed in this application divided the horizon into several layers that are drilled, loaded and fired in one cycle. Within each layer the blasts have different powder factors, inter-hole delays and directions of initiation. Additionally, delays of several seconds may be used between the various layers (Goswami and Brent, 2006; Goswami, Brent and Rutledge, 2006; Goswami, Brent and Hain, 2008). To this end, the following factors had to be considered:

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**FIG 6** – Schematic of vertical section through the bench for ‘baby decking’.

**FIG 7** – Baby deck modelling result.

**FIG 8** – Profile of coal seam showing pre- and post-blast location of the top of coal for a baby deck blast.
the mine plan needs to support the extra drill and blast time (approximately 15 per cent) for this methodology where used
the mining benefit needs to outweigh the extra drill and blast cost (approximately ten per cent).
Therefore, to achieve the optimum results, a close working relationship between the operational and mine planning areas was developed with the following changes carried out:
the mining blocks were adjusted along the strip such that each blast can be completed to meet the extraction and coal mining schedule
processes such as drill preparation processes were changed to meet the standard required
survey control improved such that the drilling continuity was maintained
drilling managed in a systematic manner progressing along strip in line with the mining schedule
the recording touch coal information was appropriately implemented.
The methodology as applied is illustrated in Figure 10 and the modelling result is shown in Figure 11. The aim of this process is to maximise forward movement of material for excavation by dozer and excavator/truck whilst minimising coal damage.
After excavation, the survey of the coal roof and edge was required to be carried out and analysed with a correlation to the previous strip coal roof survey such that damage to coal roof and edge movement could be assessed. From this further adjustments were carried out.
To achieve the required results, an accuracy of 0.5 m was needed in all facets of the preloading (dipping) and loading process. Due to the variation in coal dip along and across strike, the blasthole loading and the location of the deck varied for each blasthole requiring hole-by-hole load sheets. The location of the inert deck varied with the dip to minimise the risk of damage to the coal edge whilst delivering the required movement. These changes in the design and implementation processes reduced the coal loss by managing the movement of material into the void. Examples of the results from the coal roof survey are shown in Figures 12 and 13. From analysis of survey measurements taken over the strip the coal loss was calculated to be 0.7 per cent. This was a significant reduction from the 8.5 per cent using the ‘baby deck’ system and the 11.5 per cent using good QA/QC practices. The site evaluated the changes implemented achieved a reduction in coal loss of approximately 100 000 t
of coal when compared to that achieved using previous standard practices.

**CONCLUSIONS**

The work at this mine site has shown that coal loss can be reduced by the implementation of a variety of changes in the drill and blast, mine plan and operational processes. An important driver was the need that the changes required need to meet operational requirements to meet the coal schedule. The following changes were implemented to achieve this:

- the touch coal information from the drillers were important to understand the coal seam location for use in the loading design
- training and calibration of drillers regularly to ensure that the touch coal information being recorded is accurate via gamma logging on a regular basis
- survey measurement to understand the coal loss and the likely mechanisms of these losses and adjustments to future designs being noted
- operational mentoring to ensure all personnel understand their role in delivering the result in areas such as bench preparation and blasthole measurement, which needs to be to an accuracy of 0.5 m
- coal roof loss can be managed by implementing a robust QA/QC process using appropriate backfill material such as gravel to the required accuracy
- the drill and blast process for Stratablast required an additional 15 per cent extra time, therefore the mine blocks were adjusted to meet the required mining schedule
- the equipment (dozers and excavators) achieved the rates required by the mining schedule
- the reduction in coal loss of approximately 100 000 t was greater than the ten per cent increase in drill and blast cost.

In this case study, coal edge loss was reduced by 33 per cent by the use of ‘baby deck’ methodology to 8.5 per cent and by 95 per cent to less than one per cent by the use of the Stratablast methodology. It was noted that operational and environmental risk constraints resulted in other options of coal loss management such as buffering of the coal edge and ‘dynamic buffering’ not being evaluated.

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**REFERENCES**


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