A model for direct dragline casting in a dipping coal-seam

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Synopsis

This article introduces a computer model, which emphasizes panel design for draglines deployed in direct side-casting mode. The study covers flat and inclined coal-seam conditions with the dragline operating along the strike-line. Two casting methods are embedded in the model: material is placed in the open set adjacent to the one on which the dragline is located (the DNS method) and material is placed in the open set adjacent to the one the dragline excavates (the DND method). While in the first method the unproductive walking time is reduced as the set is enlarged, in the second method the cycle time is lessened as the dragline swings along an acute angle. The side-casting model is shaped so as to provide several panel configurations instead of a single one to conform to the characteristics for an opencast mine. This is achieved by assigning the pit width an interval of values ranging from a minimum to a maximum. The model includes solutions to other critical design parameters such as: set length, swing angles at key cut and main cut positions, and required dragline reach at key cut and main cut positions.

The model outcomes reveal the following: the stripping operation is largely affected when the coal-seam is inclined. The downhill spoiling mode should be applied wherever possible. The DNS pattern allows wider pit width intervals as well as longer sets and longer reaches.

Introduction

Fossil fuels such as coal, petroleum and natural gas are regarded as raw materials for energy as well as for the main inputs of many industries. With current rates of consumption, it is estimated that petroleum, natural gas and coal reserves will be exhausted in 40, 60 and 200 years, respectively. Unlike petroleum and natural gas, coal deposits are distributed throughout the crust of the earth in a much more homogeneous manner. Approximately 60 per cent of coal produced in the world per annum is used for electricity generation. This picture is expected to continue or slightly rise in the coming 10–15 years[1].

Nearly half of the total excavating/loading/hauling machinery employed by the mining industry belongs to coal mining[2]. Strip mining, where draglines are principal earthmovers, has a significant contribution in coal produced by practising surface mining methods. Excluding the former Soviet Union, dragline applications are concentrated in the following countries: the United States of America (USA), Australia, Republic of South Africa, Canada and India. Turkey follows these countries with a dragline inventory of nine units. The other countries employing draglines are: Brazil, Columbia, Mexico, England, Zambia and Zimbabwe. In the USA, draglines with bucket capacity of >30 cubic metres accounted for more than 40 per cent of total overburden moved in open-pit mines. In 1999, nearly 400 million tons of coal were produced by 56 large surface mines where draglines were employed. In other countries, 69 large-scale open-pit mines, where some 142 large draglines are employed, produce approximately 400 million tons of coal following 2.5 billion bank cubic metres of earthmoving per annum[3].

As depicted in Figure 1, in a typical dragline operation waste is cast clear of the coal seam[4] by the machine. Hence the toe-of the final spoil pile does not ride up the highwall. Direct side casting practice on flat-lying coal-seams is discussed elsewhere[5–10]. This study is concerned with dipping coal-seam conditions. It should be noted that the study does not model opencast layouts such as extended benching used for overburden thicknesses, which exceed the limitations associated with direct side-casting operations. Likewise, pre-stripping by dragline, such as chop down operation, is not considered.

Developed model

Pit geometry studies based on customary 2-dimensional sections may be misleading in determining essential pit dimensions. If a third

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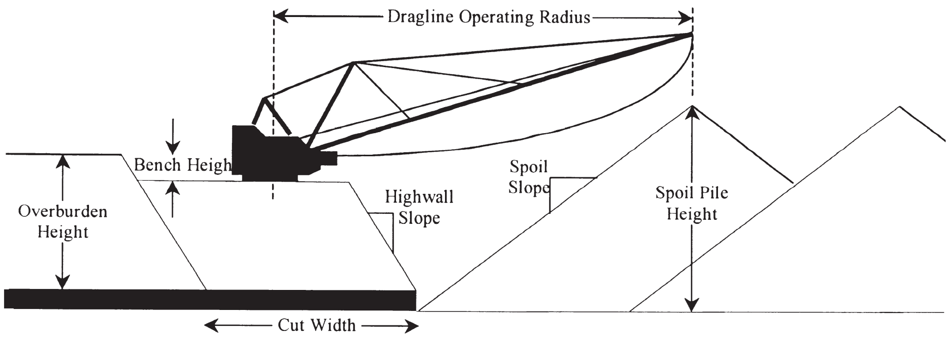

Figure 1—Typical dragline operation

dimension is added, it is seen that some of the answers might change significantly. Another important consideration in dragline pit design is the spatial position of the coal-seam, which does not need to be flat. In the case of a dipping coal-seam, dimensions regarding a flat or near-to-flat coal-seam would again be concluded with faulty magnitudes. In this study a 3-dimensional computer model is developed to assist mine planning and operational personnel to derive the most effective digging mode for the dragline employed in direct side-casting mode.

The direct side-casting model is based on a hierarchical structure (Figure 2)[11,12]. The first consideration is placed on the inclination of the coal-seam, either flat or dipping. While flat coal-seams are handled by level-spoiling rationale, there exist two spoiling alternatives for dipping coal-seams: the strike line method of downhill spoiling and uphill spoiling. Thus three operating modes are: level operation on a flat-lying seam, downhill spoiling on a dipping seam, and uphill spoiling on a dipping seam.

The model is equipped with two alternatives for waste placement. Material can be placed in the empty pit near the set on which the dragline is located or in the empty pit near the set, which the dragline digs. The former, which is called the dump-near-set (DNS) pattern, entails larger swing angles but allows the dragline to excavate large blocks at a time (Figure 3). The latter, the dump-near-dig (DND) pattern, is planned to reduce cycle times through smaller swing angles but forces the dragline to make frequent moves (Figure 4).

Pit width, particularly in moderate-to-deep overburden conditions (~35–40 m), significantly affects dragline productivity and thus, overburden removal cost. While the minimum pit width is dictated by the room needed for coal loading and hauling equipment, safety, pit dewatering requirements and in-pit benches play important roles in determining the pit width. The maximum pit width is mainly controlled by the reach of the dragline and the stripping method applied. Nevertheless, as a rule of thumb the pit should be at least as wide as it is deep[5]. Where safety is concerned, a wider pit can be maintained in deep overburden. But the problem that arises is the spoil levelling costs, which quickly rise as the peak-to-peak spacing between spoil piles increases. Where the cycle time is concerned, narrowing the pit down to a certain width can decrease cycle times as the swing angles are reduced. However, further contraction of the pit may be counter-productive as the dragline may become hoist dependent. Therefore the direct side-casting model is designed so as to allow several pit width values and pit configurations, depending on dragline dimensions in order to carry out sensitivity analyses on crucial pit dimensions.

Testing the model

Parametric studies are done with the data representing the characteristics of the virtual surface coal-mine illustrated in Table I. Information on seven arbitrarily selected draglines ranging from small to large in dimensions and capacity are given in Table II.

The direct side-casting model is executed for coal-seam inclination values of 0 to 40 degrees with 5-degree increments. For each seam inclination, both DNS and DND spoiling patterns are executed for W_{min}, W_{mid} and W_{max} cases. The broad results of the model run are presented in Table III. Results reached on parameters that have an impact on dragline productivity and those related to spoiling patterns are given in the following sections.

The results of the run indicate the following:

- At level or shallow coal-seam inclination, draglines are allowed to operate in a larger pit width interval
- Large draglines offer larger pit width ranges
- The DNS pattern offers larger pit width intervals than does the DND pattern
- In the DNS pattern, as coal-seam inclination increases, larger pit width values are reached in downhill mode. Conversely, in the DND pattern, larger pit width values are reached in uphill mode
- The uphill operating mode demands, longer operating radius.

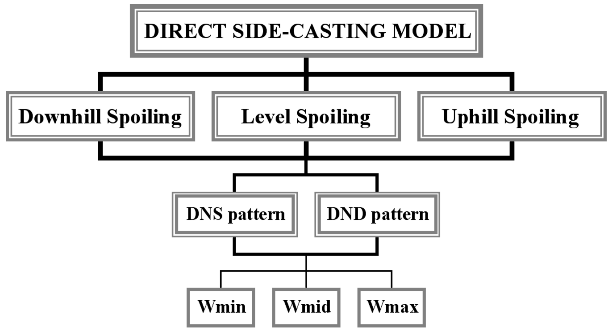

Figure 2—Hierarchical control mechanism of the model

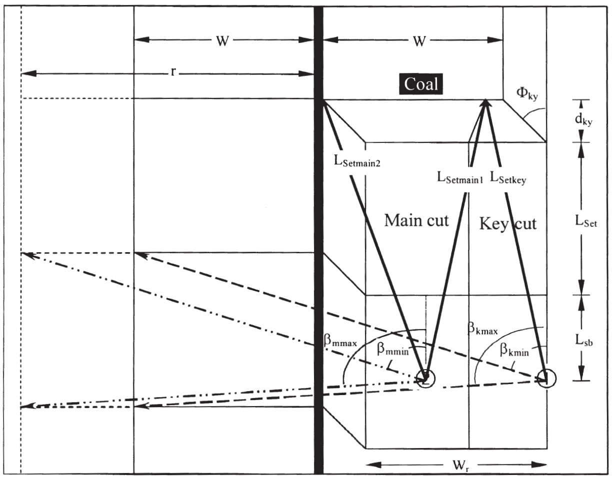

Figure 3—Dumping near the set on which dragline is located (DNS pattern)

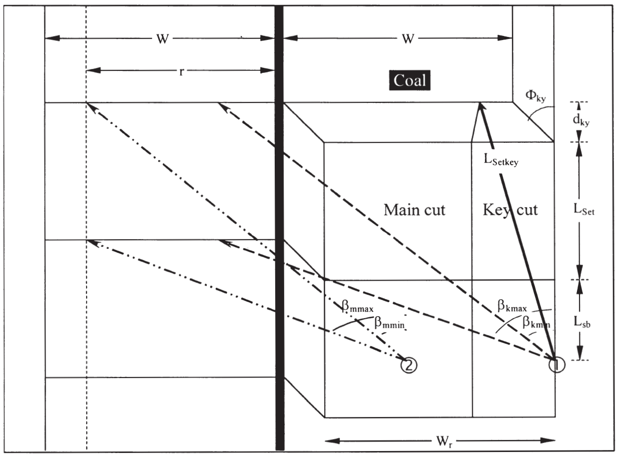

Figure 4—Dumping near the set on which dragline digs (DND pattern)

Results of the DNS pattern

Set length (L_{Set})

A set represents the space in the long direction of the panel within which excavation is made from an arrangement of digging positions before the dragline advances to the next digging positions. Owing to the fact that every point within a set must be spanned by the reach of the dragline, three sets are envisaged considering the position of the dragline on the bench: L_{Setkey} represents the set distance when the dragline is sitting on the key cut position. Similarly, $L_{Setmain1}$ and $L_{Setmain2}$ stand for the sets when the dragline is on the main cut position.

- ➤ The characteristic reaction of the three set types as the pit extends from a minimum (W_{Min}) to a maximum (W_{Max}) width is given below. A plot of level pit width (W_r) vs. set length (L_{Set}) representing the typical behaviour of all draglines is illustrated in Figure 5:
  - For all operating modes $L_{Setmain2}$ always maintains a constant figure.
  - For level operating mode, L_{Setkey} is fixed while $L_{Setmain1}$ shrinks gradually.
  - For downhill operating mode, L_{Setkey} extends steadily while $L_{Setmain1}$ shortens continuously (see Figure 3).
  - For uphill operating mode, LS_{etkey} and $L_{Setmain1}$ decrease continuously.
- ➤ Set length is directly proportional to the operating radius of the dragline. Larger units operate on longer sets while smaller ones dig shorter sets.
- ➤ For all operating modes, as the pit is widened the set is shortened. For level and downhill casting it is noteworthy that the set shrinks after a certain width of the pit. The cause is that the model selects the shortest one as the representative set for every single pit width value. For level and downhill operating modes, set length is governed firstly by $L_{Setmain2}$ and then by $L_{Setmain1}$. For uphill operating mode, however, set length, which is fixed firstly by L_{Setkey} and then by $L_{Setmain1}$, shortensconsistently.
- ➤ Set length is inversely proportional to the coal-seam's inclination. The more inclined the coal-seam, the shorter a set becomes. For downhill casting, the effect of seam inclination becomes more apparent after a seam inclination of 20 degrees. On the other hand, for uphill casting the effect is immediate, starting at 5 degree of seam inclination and becoming more perceptible as the pit widens.

Set area (A_{Set})

- ➤ The largest sets are reached at level spoiling mode (Figure 6).
- ➤ Set area is directly proportional to the size of the dragline. The larger the dragline, the larger the set area becomes.
- ➤ For all excavation modes, set area is directly propor-

Table I

Characteristics of the surface mine

Overburden bench thickness	20 m
Coal seam thickness	5 m
Coal seam inclination	0–40 degrees
Highwall angle	80 degrees
Coal seam bench angle	85 degrees
Spoil pile angle	38 degrees
Overburden swell factor	35 per cent

Table II

Basic dimensions of draglines tested

Dragline	Operating radius (m)	Dumping height (m)	Digging depth (m)	Maximum allowable load (kg)
#1	60.0	30.8	48.8	54432
#2	68.6	37.2	41.1	106596
#3	77.7	38.1	45.7	120204
#4	86.3	44.8	35.1	127008
#5	92.4	50.3	48.8	165564
#6	102.1	53.0	45.7	237233
#7	111.9	61.0	67.1	265356

Table III

Results of the model run showing pit width intervals and failure explanations

Dip ⇒	0°		5°			
Mode ⇒	DNS	DND	DNS		DND	
Dragline ⇓	Level	Level	Downhill	Uphill	Downhill	Uphill
#1	①	②	14.9–34.3	①	②	②
#2	21.0–27.0	②	21.0–41.2	22.1–23.3	②	②
#3	22.1–48.0	②	22.1–51.0	22.1–31.4	22.1–35.3	②
#4	24.3–56.0	24.3–40.0	24.3–60.8	24.3–51.6	24.3–46.1	28.3–28.3
#5	25.1–63.0	25.1–49.0	25.1–66.7	25.1–57.7	25.1–53.0	25.1–27.3
#6	28.3–72.0	28.3–57.0	28.3–76.5	28.3–65.8	28.3–61.8	28.3–42.5
#7	30.5–81.0	30.5–67.0	30.5–87.3	30.5–74.9	30.5–71.6	30.5–57.7

Dip ⇒	10°				15°			
Mode ⇒	DNS		DND		DNS		DND	
Dragline ⇓	Downhill	Uphill	Downhill	Uphill	Downhill	Uphill	Downhill	Uphill
#1	14.9–36.3	①	②	③	14.9–37.7	①	②	④
#2	21.0–43.9	①	②	③	21.0–46.0	①	②	④
#3	22.1–54.4	①	22.1–39.1	③	22.1–57.1	①	22.1–40.5	③
#4	24.3–63.9	24.3–25.4	24.3–48.7	③	24.3–68.1	①	24.3–50.6	③
#5	25.1–70.6	25.1–36.6	25.1–56.3	②	25.1–76.4	①	25.1–58.9	③
#6	28.3–81.1	28.3–52.8	28.3–64.9	②	28.3–79.1	①	28.3–69.0	③
#7	30.5–92.6	30.5–68.0	30.5–75.4	30.5–32.5	30.5–78.2	30.5–37.4	30.5–78.2	②

Dip ⇒	20°				25°			
Mode ⇒	DNS		DND		DNS		DND	
Dragline ⇓	Downhill	Uphill	Downhill	Uphill	Downhill	Uphill	Downhill	Uphill
#1	14.9–39.6	⑤	14.9-26.4	⑤	14.9–40.8	⑤	14.9–26.6	⑤
#2	21.0–47.5	①	②	④	21.0–47.4	①	②	④
#3	22.1–58.9	①	22.1–42.2	④	22.1–47.4	①	22.1–42.4	④
#4	24.3–58.9	①	24.3–52.8	③	24.3–49.1	①	24.3–48.2	④
#5	25.1–58.9	①	25.1–59.8	③	25.1–48.2	①	25.1–49.1	④
#6	28.3–60.7	①	28.3–59.8	③	28.3–48.2	①	28.3–48.2	④
#7	30.5–59.8	①	30.5-–59.8	③	30.5–48.2	①	30.5–48.2	④

Dip ⇒	30°				35°			
Mode ⇒	DNS		DND		DNS		DND	
Dragline ⇓	Downhill	Uphill	Downhill	Uphill	Downhill	Uphill	Downhill	Uphill
#1	14.9–40.5	⑤	14.9–24.9	⑤	14.9–35.9	⑤	②	⑤
#2	21.0–40.5	①	②	④	21.0–35.2	②	②	④
#3	22.1–40.5	①	22.1–40.5	④	22.1–35.2	①	22.1–35.2	④
#4	24.3–40.5	①	24.3–40.5	④	24.3–35.2	①	24.3–35.2	④
#5	25.1–40.5	①	25.1–41.2	④	25.1–35.9	①	25.1–35.9	④
#6	28.3–42.0	①	28.3–41.2	④	28.3–35.9	①	28.3–35.9	④
#7	30.5–41.2	①	30.5–41.2	④	30.5–35.9	①	30.5–35.9	④

① Required horizontal reach at main cut position is larger than available reach of the dragline under consideration.
② The designed set is too short to operate in.
③ The set with respect to main cut position cannot be formed due to insufficient dragline reach.
④ The set with respect to key cut position cannot be formed due to insufficient dragline reach.
⑤ The pit is too narrow to construct a key cut.

tional to pit width but not maximized at the largest pit because, after a certain value of pit width a marginal decrease in set length becomes more than a marginal increase in pit width.

- In both downhill and uphill operating modes set area is inversely proportional to coal-seam inclination. Also, the marginal decrease in set area for uphill mode is more than that for downhill mode.

Key cut swing angle (β_{Key})

- The material is swung and cast along the largest angle at level operating mode.
- Swing angle is directly proportional to the size, operating radius in particular, of the dragline. The larger the dragline, the wider the pit becomes and thus the larger the key cut swing angle.

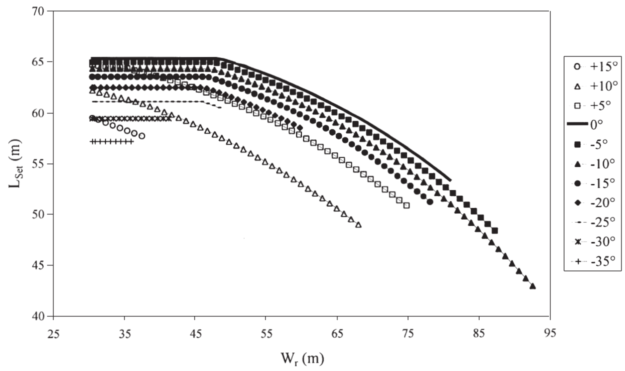

Figure 5—W_r vs. L_{Set} for dragline #7 in the DNS pattern

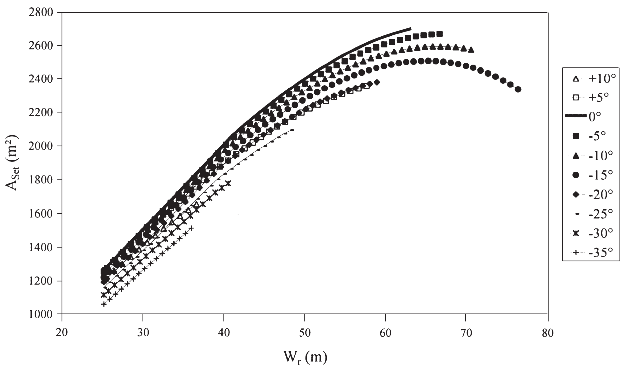

Figure 6—W_r vs. A_{Set} for dragline #5 in the DNS pattern

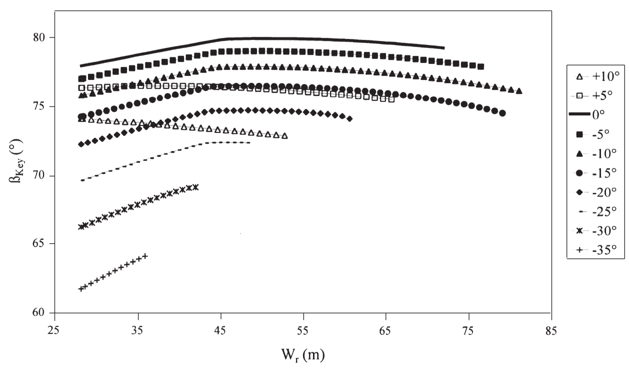

Figure 7—W_r vs. β_{Key} for dragline #6 in the DNS pattern

- ➤ For flat and downhill excavation modes, swing angle increases up to a certain value of pit width and then starts declining towards W_{Max}. The reason is that the swing angle is modelled to be a function of set length (L_{Set}), which in turn is a function of pit width and required operating radius at key cut position (R_{Key}). Up to that specific pit width value, where β_{Key} is maximized, the marginal decrease in L_{Set} is less than the marginal increase in R_{Key}. Thus the swing angle keeps rising. After that point, the situation is reversed and the swing angle starts to reduce. For uphill working mode, the swing angle follows a consistent declining trend.
- ➤ In both of the inclined-seam operating modes key cut swing angle is inversely proportional to coal-seam inclination. The marginal decrease in swing angle for uphill mode is more than that for downhill mode (Figure 7).

Main cut swing angle (β_{Main})

- ➤ The material is swung and cast along the largest angle at level operating mode (Figure 8).
- ➤ Swing angle is directly proportional to the size, operating radius in particular, of the dragline. The larger the dragline, the larger the key cut swing angle becomes.
- ➤ For flat and downhill excavation modes, up to 20 degrees of seam inclination, swing angle increases very slightly up to a certain level of pit width and then starts declining towards W_{Max}. For higher seam inclination values, swing angles tend to decrease from W_{Min} to the maximum width in which the dragline is allowed to operate. This behaviour can be explained with the same reasoning used for key cut swing angle cases. In uphill spoiling mode, the swing angle follows a consistent declining trend.
- ➤ In both of the inclined-seam operating modes main cut swing angle is inversely proportional to coal-seam inclination. The marginal decrease in swing angle for uphill mode is more than that for downhill mode.

Required reach at key cut position (R_{Key})

- ➤ For all operating modes required, reach increases with pit width and is maximized at the largest pit (W_{Max}). This can be attributed to gradual enlargement of the pit (Figure 9).
- ➤ Required reach is directly proportional to the size of the dragline. The larger the dragline the larger the reach required.
- ➤ The required reach at key cut position is inversely proportional to the coal-seam inclination in downhill casting mode. On the contrary, it is directly proportional to the coal-seam inclination in uphill casting mode. Increase in reach at uphill mode is larger than decrease in downhill mode per increment in coal-seam dip.

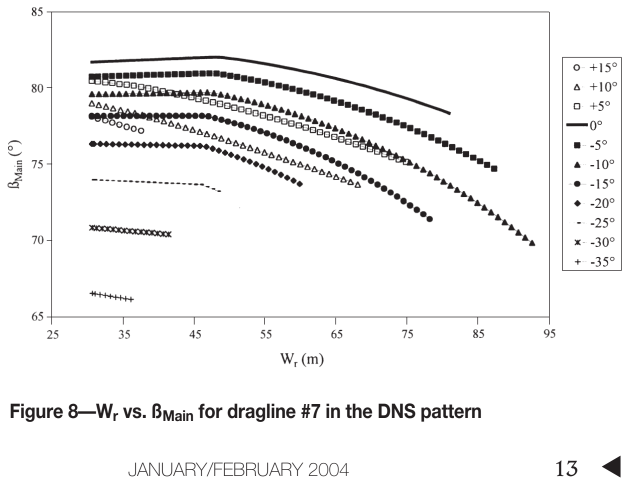

Figure 8—W_r vs. β_{Main} for dragline #7 in the DNS pattern

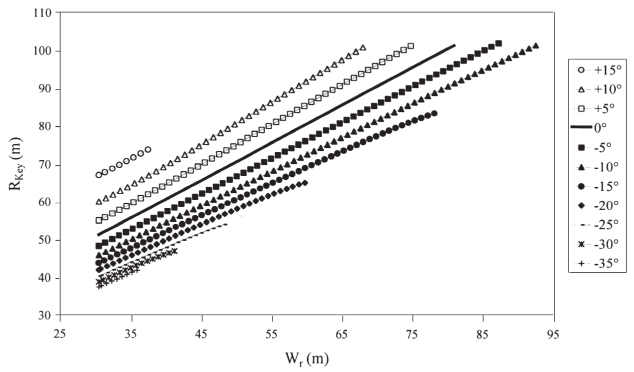

Figure 9—W_r vs. R_{Key} for dragline #7 in the DNS pattern

Required reach at main cut position (R_{Main})

- ➤ For level and uphill spoiling the required reach increases with pit width and is maximized at the largest pit. This relation is valid for downhill spoiling at shallow (<10°) coal-seam inclination. But at steeper angles (>10°) the required reach at spoil side decreases as pit width increases (Figure 10).
- ➤ For uphill mode, the required reach extends with coal-seam dip. For downhill a mode shorter reach is needed as the coal-seam inclines more steeply. Increase in reach at uphill mode is larger than the decrease in downhill mode per increment in coal-seam dip.
- ➤ The largest pit is reached when any of the conditions $R_{Key} > D_{Key}$ or $R_{Main} > D_{Main}$ is satisfied first. In level casting and downhill casting, pit width is controlled by R_{Key} whose marginal rate of increase is higher than R_{Main} as D_{Key} and D_{Main} are assigned a fixed value, which is independent of pit width. In downhill casting, beyond a coal-seam inclination of 15°, the largest pit is not reached from the point of view of the above conditions due to the inability of the dragline to construct a key cut. Thus, larger pits can be excavated from only the main cut position. In uphill excavation, conversely, pit width is controlled by R_{Main} in a similar manner.

Results of the DND pattern

Set length (L_{Set})

- ➤ Set length is inversely proportional to pit width (W_r in Figures 3 and 4) in a similar fashion explained in the DNS pattern (Figure 11).
- ➤ The larger the dragline, the longer the set length.
- ➤ For downhill spoiling, set length is directly proportional to coal-seam's inclination up to 20 degrees. For greater seam inclination, set length is reduced slightly. For uphill casting, set length decreases drastically with increasing seam inclination.

Set area (A_{Set})

- ➤ For all excavation modes, set area is directly proportional to pit width but not maximized at the largest pit because, after a certain value of pit width, the set starts shortening at a rate that is higher than the rate at which the pit widens (Figure 12).
- ➤ Set area is directly proportional to the size of the dragline. The larger the dragline, the larger the set area.
- ➤ For downhill spoiling, set area is directly proportional to the coal-seam's inclination up to 20 degrees. It decreases for greater seam inclination values. For uphill casting, set area decreases drastically with increasing seam inclination.

Key cut swing angle (β_{Key})

- ➤ For all excavation modes, swing angle increases with pit width and is maximized at the largest pit (Figure 13).

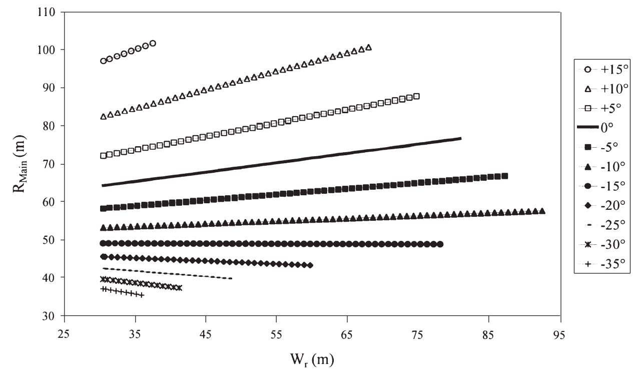

Figure 10—W_r vs. R_{Main} for dragline #7 in the DNS pattern

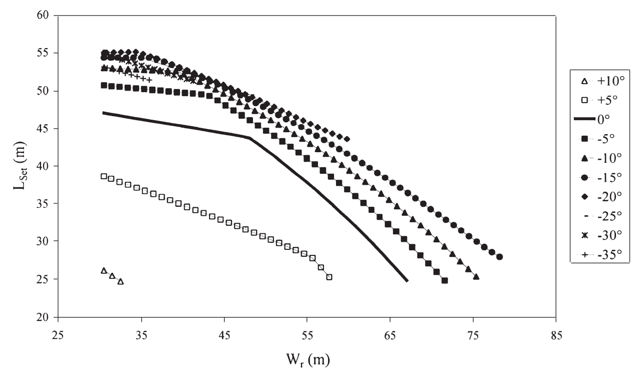

Figure 11—W_r vs. L_{Set} for dragline #7 in the DND pattern

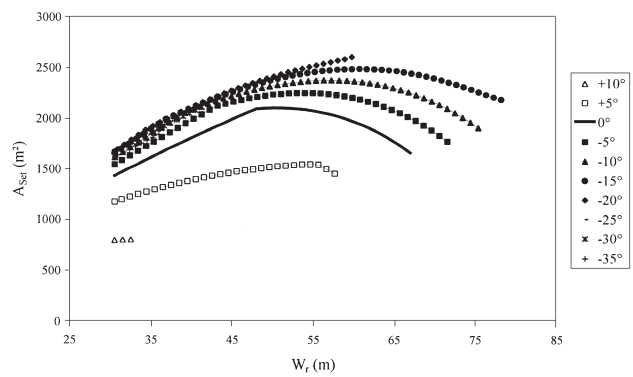

Figure 12—W_r vs. A_{Set} for dragline #7 in the DND pattern

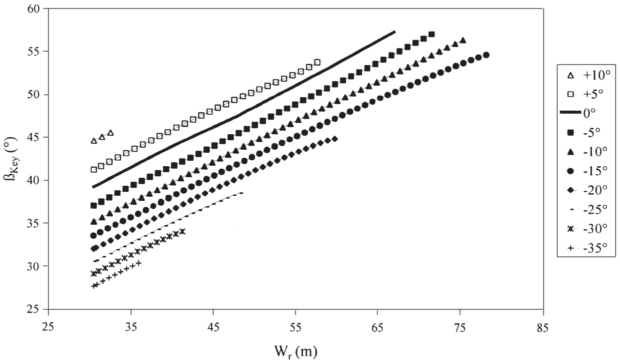

Figure 13—W_r vs. $ß_{Key}$ for dragline #7 in the DND pattern

- The larger the dragline, the smaller is the swing angle.
- The steeper the coal-seam the smaller the key cut swing angle for downhill excavation and the greater for uphill excavation. Marginal change in swing angle with respect to the coal-seam inclination is reflected more in uphill spoiling.

Main cut swing angle ($ß_{Main}$)

- Swing angle is inversely proportional to the size of the dragline. The larger the dragline, the smaller the main cut swing angle (Figure 14).
- For flat, uphill and downhill casting of up to 20 degrees of seam inclination, swing angle is directly proportional to level pit width. For steeper inclination of downhill casting, swing angle declines toward W_{Max}.
- The steeper the coal-seam, the smaller the main cut swing angle in downhill spoiling. Conversely, it is directly proportional to coal-seam inclination in uphill casting. The marginal increase in swing angle for uphill mode is more than the marginal decrease for downhill mode.

Required reach at key cut position (R_{Key})

- Required reach is directly proportional to the size of the dragline (Figure 15).
- For all casting modes, required reach is directly proportional to level pit width.
- The steeper the coal-seam, the smaller the required reach at key cut position in downhill spoiling. Conversely, it is directly proportional to coal-seam inclination in uphill casting. The marginal increase in uphill mode is more than the marginal decrease for downhill mode.
- In DND operating mode, pit width is controlled in a way similar to the DNS mode, with one exception: D_{Key} and D_{Main} are positively correlated with pit width.

Required reach at main cut position (R_{Main})

- Required reach is directly proportional to the size of the dragline (Figure 16).
- For level and uphill spoiling, required reach increases with pit width and is maximized at the largest pit. This relationship also works for downhill spoiling up to 15 degrees of coal-seam inclination. But at steeper angles, required reach decreases as pit width increases.
- For uphill mode, required reach extends with coal-seam dip. For downhill mode shorter reach is needed as the coal-seam inclines more steeply. Increase in reach at uphill mode is larger than the decrease in downhill mode per increment in coal seam dip.

Results on the basis of operating patterns

- Swing angles in the DND pattern are smaller.
- Set lengths in the DNS pattern are longer.
- A dragline operating in the DNS pattern can excavate thicker overburden.
- Available reaches in the DNS pattern are longer.
- The DNS pattern offers more a flexible environment in terms of pit geometry.

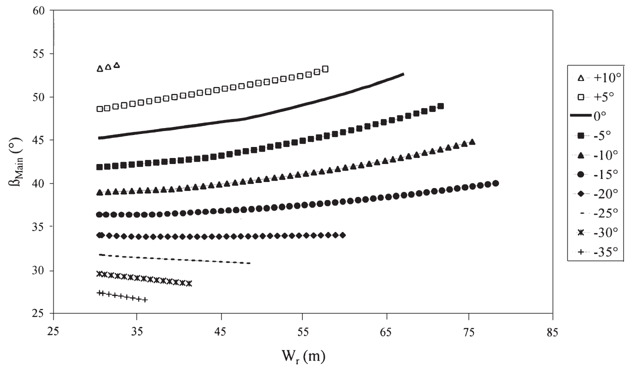

Figure 14—W_r vs. $ß_{Main}$ for dragline #7 in the DND pattern

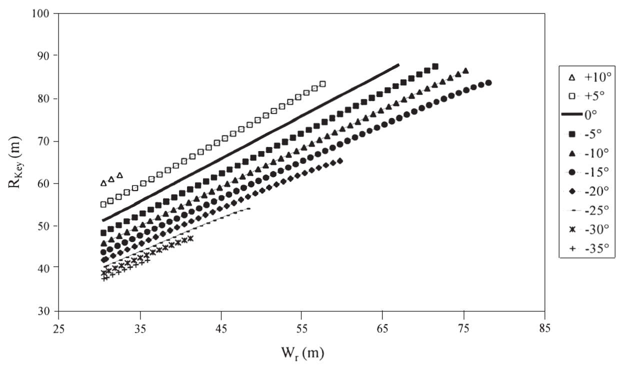

Figure 15—W_r vs. R_{Key} for dragline #7 in the DND pattern

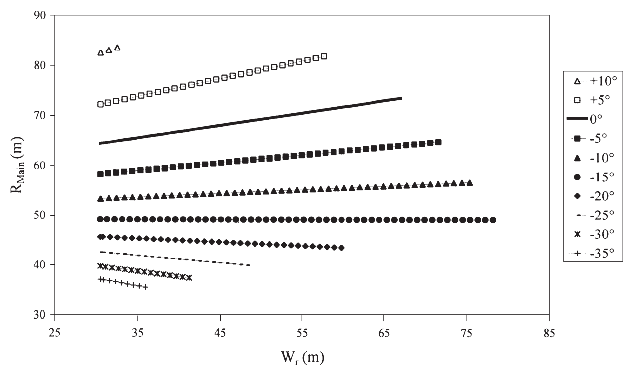

Figure 16—W_r vs. R_{Main} for dragline #7 in the DND pattern

Conclusions

This study presents a computer model for dragline selection deployed in direct side casting. The developed model can be utilized on level or inclined coal-seam conditions in three operating modes: level casting, downhill casting, and uphill casting. The model offers two alternatives for spoil placement: waste can be dumped into the set, which is located next to the one on which the dragline is positioned (the DNS pattern) or waste can be dumped into the set, which is next to the one the dragline digs (the DND pattern). Several pit configurations can be obtained for a dragline by assigning an interval of pit width values, among which a proper selection could be made.

The main conclusions drawn from the study are as follows:

- A dragline can cope with thicker waste in downhill casting. Small draglines may fail to operate in uphill mode.
- The uphill casting mode requires that the dragline should have greater dumping height and it cannot make proper use of the available spoil room. Thus, when all the design parameters are kept equal, the pit must be kept shorter than the downhill mode.
- In the case of an inclined coal-seam, the downhill mode should be preferred.
- The DNS spoiling pattern should be preferred. Although swing angles in this pattern are higher than those in the DND pattern, they are more than compensated for mainly by larger pits. Besides, required dimensions that a dragline should provide such as dumping height and operating radius, are smaller.

Recommendations

The developed model could be supplemented and improved by the following studies:

- Inclusion of means, which would enable the model to cover rehandling and prestripping operations by draglines.
- In its current form, the model constructs spoil piles with a continuous ridge line parallel to the direction of dragline advance. Modelling spoiling practices which, result from conical spoil piles or curvilinear ridge lines, would enable the model to reveal more efficient use of the spoil room.

Nomenclature

Φ_{ky}	Cut face angle (degrees)
β_{mmin}	Minimum swing angle from main cut position (degrees)
β_{mmax}	Maximum swing angle from main cut position (degrees)
β_{kmin}	Minimum swing angle from key cut position (degrees)
β_{kmax}	Maximum swing angle from key cut position (degrees)
β_{Main}	Average swing angle at main cut position (degrees)
β_{Key}	Average swing angle at key cut position (degrees)
A_{Set}	Area of set to be dug (m^2)
d_{ky}	Cut face distance (m)
L_{sb}	Setback distance (m)
L_{Set}	Set length (m)
L_{Setkey}	Set length as measured from key cut position (m)
$L_{Setmainx}$	Set lengths (1 and 2) as measured from main cut position (m)
r	Effective reach as measured from coal seam toe (m)
R_{Key}	Required operating radius at key cut position (m)
R_{Main}	Required operating radius at main cut position (m)
W	Pit width (m)
W_r	Level pit width in the case of inclined coal-seam (m)

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