Cycle time and idle time analysis of draglines for increased productivity—
A case study

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In India, massive opencast mines are being planned, with dragline as an excavator, to strip out large volumes of overburden (O/B) at a high stripping ratio. The increased use of draglines is primarily because the draglines have tremendous flexibility of operation at varying O/B depths. Besides, it is capable of giving higher rate of O/B removal at relatively low operating cost. However, at the same time, it must be distinctly borne in mind that the dragline is single most expensive equipment to be procured by a mine. Hence, analysis of cycle time and idle time is of tremendous significance with such capital intensive equipment. Such analysis paves the way for improvement in the utilization, production and productivity of this equipment. The present study is based on field investigation conducted on draglines in one of the most prestigious opencast coal mines of Coal India Limited. The study critically analyses the cycle time and the idle time distribution of the draglines, as operating in the field.

The increased demand of coal, as a source of fuel and as a source of power, owing to rapid industrialization and population explosion, has forced the opencast coal mines to turn towards higher mechanization for extraction of coal and removal of O/B as well. To cope up with the higher demands, deeper opencast mines, involving the handling of huge bulk of O/B at a high stripping ratio are currently being planned. These deep and large opencast mines have led to several positive developments in the state of mechanization. It has definitely paved the way for deployment of large sized heavy earth moving machines.

Presently, in opencast coal mines, large number of heavy earth moving equipment are being used to achieve required target. The system of O/B removal must be efficient and economical. The choice of the machine for O/B removal is usually governed by the geominging conditions like thickness of O/B layer and coal seam, gradient of the seam, pit geometry, strike length, the rate of O/B removal, life of mine, geological disturbances and capital availability. Draglines are commonly deployed to remove the O/B material that is dug, conveyed and unloaded in relatively long and narrow open pit excavated as a part of a series of adjacent and parallel pits. Owing to its long reach and absence of auxiliary haulage equipment, dragline has gained tremendous significance. It strips as well as reclaim the O/B hand in hand. The present paper discusses the various aspects of the operation of dragline in form of case study of an Indian opencast coal mine.

Dragline Productivity

When considering the method of O/B removal to be employed several factors need to be taken into account which include: (i) total volume of overburden (O/B) to be removed and the ratio of O/B to coal by volume, (ii) rate of O/B removal necessary to achieve the targetted coal output, (iii) the geology of the site with regard to seam dip, the significant faulting and the depth of interburden between seams, and (iv) total owning and operating costs.

The objective of deploying dragline is to remove maximum possible amount of O/B in the shortest possible time. To evaluate the performance of a dragline of particular bucket capacity, the cycle of operation and average cycle time must be known. It can be seen that decrease in cycle time and increase in availability and utilization of the machine can improve the overall productivity of the dragline.

Dragline cycle of operation comprises a number of time elements like scooping, swinging, dumping and swinging back time. Scooping time is the time taken in filling the dragline bucket and maneuvering. Swinging time is the time consumed in swinging the bucket from the end of scooping time till it starts releasing the material from the bucket. Dumping time
involves the time taken in releasing the material from the starting of releasing the material till the bucket discharges completely and swinging back time is the time taken since completion of dumping the material till the bucket touches the bank. If we are able to reduce only a few seconds in a cycle time of a dragline, there would be tremendous improvement in production as well as profit.

A basic approach to estimating dragline production involves use of a standard cyclic excavator equation such as the one below that has been tailored to monthly dragline output:

\[
O = \frac{B \times BF \times HS \times A \times J \times 3600}{(1+S) \times C \times (1+R)}
\]

where,

- **O** = output (bcy/month)
- **B** = bucket size (yd³)
- **BF** = bucket fill factor
- **HS** = hours scheduled/month
- **A** = maintenance availability (% of schedule time machine is available for stripping/100)
- **J** = job factor (% of time that machine is available for stripping)
- **S** = swell percentage/100
- **C** = average cycle time (s)
- **R** = rehandle percentage/100

It is evident from above equation that higher level of productivity can be obtained by reducing the amount of rehandle and cycle time.

Another important index is a production index, which can be defined as the bank measure of O/B volume moved per period per rated bucket volume. This measure is quite helpful in comparing the productivity of different draglines of different make and capacities. The index can also be useful in the machine selection procedure when used to calculate required bucket capacity per period given the O/B volume per period. ‘Production Rate’ can be defined as the bank measure of O/B per period. This bank measure is an index helpful in production forecasting and scheduling.

In order to reduce the bucket cycle time, global efforts are being put to reduce a portion of bucket cycle time consumed in scoop and swinging operations. Along with reduction in bucket cycle time, an appreciable increase in bucket fill factor is necessitated. With the advent of computer aided design (CAD) and finite element method (FEM) analysis, several innovations have been achieved in the bucket design. Research and development efforts have been concentrated towards the innovative bucket designs which has resulted into increased bucket fill factor, greater breakout force, reduced bucket cycle time and increased bucket life. Today's buckets are, hence, a careful balance of capability vis-a-vis durability.

Swing angle is an important aspect of dragline productivity which, generally, varies from 30° to 180°. Once a dragline has been positioned, the swing angle becomes important. Increase in swing angle increases the swinging to time and swinging back time.

Besides the studies on cycle time, it is also essential to investigate the idling time of these equipment. This investigation throws light on the potential reasons that lead to the idling under the actual field operating condition. For high rate of removal of O/B by excavations and for optimum utilization, idling time must be kept minimum.

In order to ensure better performance and cost effectiveness of the dragline system, Fishler has stated that it may pay to operate with two smaller machines in tandem rather than one large machine.

Percentage of rehandling is also an important parameter affecting the dragline productivity. Sharma expressed that percentage of rehandling increases with the decrease in boom length and angle of repose of material. Other parameters which affect the dragline performance are O/B depth, swell factor, angle of repose of spoil pile, pit configuration, bench height, machine characteristics and operators efficiency.

**Case Study**

To accomplish meaningful results field study was conducted in one of the major opencast coal mines of Coal India Limited. On the basis of field observations the performance evaluation of the existing dragline system operating in O/B, has been undertaken. Field

<table>
<thead>
<tr>
<th>Table 1—Dragline techno-operational parameters</th>
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<tbody>
<tr>
<td>(Courtesy : Northern Coalfields Ltd.)</td>
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<tr>
<td>Dragline type                     : Walking</td>
</tr>
<tr>
<td>Bucket capacity                : 24 m³</td>
</tr>
<tr>
<td>Boom length                   : 96 m</td>
</tr>
<tr>
<td>Boom angle                    : 35°</td>
</tr>
<tr>
<td>Digging reach                  : 85 m</td>
</tr>
<tr>
<td>Dumping reach                  : 85 m</td>
</tr>
<tr>
<td>Digging height                 : 43 m</td>
</tr>
<tr>
<td>Dumping height                 : 40 m</td>
</tr>
</tbody>
</table>
Table 2—Dragline time study (dragline type=walking, 24/96; bench height=30 m)

<table>
<thead>
<tr>
<th>Swing angle</th>
<th>Scooping time (s)</th>
<th>Swinging time (s)</th>
<th>Dumping time (s)</th>
<th>Swinging back time (s)</th>
<th>Total time (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>60°</td>
<td>21.75</td>
<td>20.42</td>
<td>07.10</td>
<td>20.12</td>
<td>68.54</td>
</tr>
<tr>
<td>90°</td>
<td>22.70</td>
<td>23.10</td>
<td>06.40</td>
<td>22.47</td>
<td>74.67</td>
</tr>
<tr>
<td>120°</td>
<td>23.78</td>
<td>25.10</td>
<td>06.85</td>
<td>24.62</td>
<td>80.35</td>
</tr>
<tr>
<td>150°</td>
<td>25.72</td>
<td>26.75</td>
<td>06.95</td>
<td>25.85</td>
<td>85.27</td>
</tr>
<tr>
<td>180°</td>
<td>25.60</td>
<td>28.58</td>
<td>07.20</td>
<td>27.45</td>
<td>88.43</td>
</tr>
</tbody>
</table>

Table 3—Performance indicators for dragline for the period April 1997 to March 1998
(Courtesy: Northern Coalfields Ltd)

- Working hours: 6702
- Maintenance hours: 1088
- Back-down hours: 445
- Idle hours: 525
- Availability hours: 83%
- Utilisation: 77%
- O/B Removed: 28.5 Lac m³
- Rehandling: 10.68 Lac m³

Table 4—Productivity indices of dragline

<table>
<thead>
<tr>
<th>Performance Indicator</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent of rehandling</td>
<td>37%</td>
</tr>
<tr>
<td>Rate of O/B removal</td>
<td>425.24 m³/working h</td>
</tr>
<tr>
<td>Rate of O/B removal (including rehandling)</td>
<td>584.60 m³/working h</td>
</tr>
<tr>
<td>Production index</td>
<td>17.72 m³/working h/m³ bucket capacity</td>
</tr>
<tr>
<td>Production index (including rehandling)</td>
<td>24.36 m³/working h/m³ of bucket capacity</td>
</tr>
</tbody>
</table>

Fig. 1—Frequency distribution of a dragline cycle
observations are based on the time and motion study of all segments of cycle time like scooping, swinging, dumping and swinging back times and swing angle. These field observations have been analyzed and are presented in Tables 1-4. The frequency distribution of a dragline cycle is shown in Fig. 1.

Besides the segmental cycle time studies, a detailed field investigation was carried out to reveal the potential areas that lead to the idling of different draglines. Towards this end, the draglines, viz., 15/90 and 24/96 (15 m³ and 24 m³ bucket capacity and 90 m and 96 m boom length) operating in the field were studied. The results of the investigation for each equipment type, viz., 15/90 dragline and 24/96 dragline are shown in Figs 2 and 3.

**Results and Discussion**

**Cycle time analysis**

Based on the values obtained from the field studies, the tables and graphs are prepared and illustrated. From Tables 1-4 and Figs 1-3, it may be noted that the variation in swinging to time and swinging back time is little for constant swing angles. As swing angle varies these two time segments also vary. Dumping time is more or less constant. It is the scooping time which varies from cycle to cycle. Scooping time mainly depends upon the degree of fragmentation of O/B material that is to be handled. Hence, optimum blasting practices need to be practiced. However, in the present study, the effect of degree of fragmentation on the scooping time couldn't be studied since this factor didn't vary throughout the study.

The production index and rate of O/B removal measured in terms of O/B m³ per working hour per m³ of bucket capacity and O/B m³ per working hour are not so satisfactory. Percentage of rehandling is also large. The efficiency factor that can be expressed as multiplication of availability and utilization is quite low. For these breakdown hours, idle hours are to be minimized, and as it is proposed by many other researchers introduction of four shifts with an overlap is a good compromise for improving availability and utilization of dragline operations.

**Idle time analysis**

A close perusal of the bar charts (Figs 2 and 3), reveals that for the 15/90 dragline as well as for 24/96 dragline, there are five important reasons responsible for machine idling. These are non availability of power, dozing operation, blasting operations, idle marching and miscellaneous reasons.

In case of 15/90 dragline 24.87% of total idle hours and 26.5% of total idle hours is due to no power availability. In case of 24/96 dragline, 26.5% of dozing operations, constitute loss of 21.98% and 23.83% respectively, of total idle hours. Third major operation is blasting. In case of 15/90 dragline, it accounted to 20.94% of total idle hours. In 24/96 dragline, however, the blasting operations, which accounted for 16.11%, stood fourth. Miscellaneous operations like inspection by officers, operators not available, losses during tiffin hours and shift changeovers constituted 21.76% of total idle hours in case of 24/96 dragline and 18.58% in 15/90 dragline.

Previous studies in this direction have also revealed a significant loss in available hours of these HEMM due to blasting operations, dozing operations, tiffin periods and shift changeovers, etc.11,13

Hence, it is imperative at this stage that after analyzing the pertinent reasons for machine idling, the responsibility of idling may be systematically
divided among the managerial group, technical group and the mining group. Say, for instance, the losses due to extended tiffin periods, shift changeovers etc. can be attributed to the ‘managerial group’. Similarly losses due to non availability of auxiliary equipment/services can be attributed to the technical group and the losses due to dozing operations, machine marching, blasting operations can be assigned to the mining group. This clearcut demarcation of accountability of machine idling can substantially reduce the idling losses by giving forth to a feeling of healthy competition.

**Conclusions**

The detailed analysis of dragline productivity studies indicated that:

1. With the increase in swing angle, cycle time increases that can be reduced by proper positioning of dragline keeping in view that rehandling should be minimum.
2. There is a great variation in scooping time. However, improved bucket design and proper blasting practices can reduce scooping time.
3. Idling of dragline should not be tolerated even for a few seconds as it leads to depreciation and production losses.
4. Idling hour distribution of draglines has thrown sufficient insight into the reasons primarily responsible for machine idling in the field operating conditions.
5. Non availability of power appears to be one of the major bottlenecks in dragline performance. Hence, power availability in mines must be given attention.
6. The idea of assigning the responsibility of idling hours to the appropriate group may increase the accountability and thereby minimize the machine idling hours.
7. Productivity of the dragline can be improved by increasing utilisation of the machine by reducing the cycle time and idle time through proper planning.

**References**