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Performance assessment of draglines in opencast mines

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The present paper investigates a few important productivity parameters of draglines operating in some major opencast coal-mines in India. The parameters, such as, average total cycle time, availability, utilization, annual output and influence of fragmentation on the overall performance of the draglines, have been critically analyzed with studies in mines. The results indicate that there is a considerable scope for improvement in performance of draglines mines by reducing the cycle time, improving the maintenance strategies, reducing the idling losses and improving the degree of fragmentation, especially at the collar regions.

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The use of large walking draglines for stripping the overburden (OB) rocks in large opencast coalmines is growing steadily in India, with the result that deeper coal seam with stripping ratios of even up to 1:4 or 1:5 and gradients of up to 1 in 3 to 1 in 4 are being mined by this equipment successfully. Even thinner seams with a limiting gradient of 1 in 6 to 1 in 8 are now considered to be mineable by draglines. A dragline may be considered as one of the world’s biggest robots which is about 100 m high and is used as a walking crane in surface coal mines.

The main application of walking draglines exist in opencast coal projects where the volume of OB to be handled is many times greater than the volume of mineral to be extracted. For instance, one-meter coal seam may have thirty-meter thick cover of OB, which may still be an economic proposition to be mined by draglines.

Looking into the merits and vast scope of application of the dragline in opencast projects on one hand and large capital investment (about rupees 80 crores) incurred on procuring, operating and maintaining this equipment on the other hand, it becomes imperative to assess the performance of this equipment.

The present paper, evaluates a few important performance parameters of draglines. Such evaluations would necessarily provide the information in regard to the areas, which call for immediate attention in order to enhance the performance standards of the draglines.

The study was carried out to evaluate some major performance parameters of the draglines operating in some large opencast coalmines of our country. The chief objectives of the present work are: (i) to study the complete cycle of operation of draglines in the field and to break it up into simpler segments in order to observe and record the segmental and total cycle time for different capacity draglines operating, (ii) to evaluate the availability (A) and utilization (U) of the draglines and to critically analyze the loss of operational hours, (iii) to estimate and project the annual output of the draglines based on the recorded cycle time and evaluated availability and utilization data, and (iv) to investigate the influence of the degree of fragmentation on the cycle time, and, hence, the productivity of the draglines.

Methodology

In order to achieve the stated objectives, field scale studies and data acquisition was carried out in some large opencast coal projects of Northern Coalfields Limited and Singareni Coal Company Limited.

Time and motion studies were carried out for recording the cycle time elements. Besides, a record of working hours (WH), idle hours (IH), maintenance hours (MH) and breakdown hours (BH) were also maintained meticulously for a period of one month on various draglines under study.

Cycle time studies

For the purpose of systematic investigation, one complete cycle of operation of dragline was splitted up into four segments, namely, bucket placement and digging, swinging to, unloading and swinging back operations. Individual time for each of these parts of
operation and the total cycle time observations were made and recorded in the field. For time recording stopwatch was used.

**Evaluation of availability (A) and utilization (U)**

To evaluate the A and U, field data was acquired and maintained on day-to-day basis on all the draglines under study. This acquired data was substituted in Eqs (1) and (2) for the computation of A and U.

\[
A = \frac{SSH - (MH + BH)}{SSH} \quad \ldots (1)
\]

\[
U = \frac{SSH - (MH + BH + IH)}{SSH} \quad \ldots (2)
\]

where, SSH is scheduled shift hours, MH is maintenance hours, BH is breakdown hours and IH is idle hours.

Further, a detailed investigation of idle hours has been done in order to identify the major reasons responsible for non-operation of these machines in the field. The percentage-wise-break up of these idle hours has been done in order to categorically generate an idea in regard to the weightage of these major reasons.

**Projection of annual output**

Based on the observed and recorded data in terms of average total cycle time, A and U values, the annual output (P1) of the draglines under study, has been projected using Eq. (3):

\[
P1 = \frac{(B/C) \times A \times U \times S \times F \times M \times N_s \times N_h \times N_d \times 3600}{(in \ Million \ cubic \ meter)} \quad \ldots (3)
\]

where, B is bucket capacity of dragline in cubic meter, C is average total cycle time of dragline in second, S is swell factor, F is fill factor, M is machine travel and positioning factor, N_s is number of operating shifts in a day, N_h is number of operating hours in a shift and N_d is number of operating days in a year.

In the above equation, the values of average cycle time (C), A and U were substituted as per the recorded field observations. Remaining factors in the Eq. (3) (S, F, M, N_s, N_h, N_d) were substituted as per the recommendations made by CMPDI in regard to the values of these factors in Indian coal-mines. The suggested values for these factors are given in Table 1 as obtained through personal communication with CMPDI, RI-VI, Singrauli.

P1 has been termed as projected annual output because it has been computed on the basis of short-term field study and data acquisition. This projected output has been compared with the annual output norm (P) as fixed by the CMPDI, in order to provide an insight into the performance of operating draglines.

**Fragmentation versus cycle time**

During the course of fieldwork, it was observed that the cycle time of the draglines is related to the degree of fragmentation in the blasted muck piles. The digging time segment of the total cycle time was largely affected by the fragmentation. The invariable occurrence of oversize boulders at the collar region of the blasted muck piles was noticed. These oversize boulders at the collar region (upto 10 m from the top of the bench) adversely affected the bucket placement and digging segment time to a great extent. Hence, it was contemplated to precisely investigate the influence of these collars over sizes on the performance of the draglines.

**Description of the mines and draglines under study**

The field studies were conducted in four mines out of which two mines (mine 1 and mine 2) belonged to the Northern Coalfields Ltd. (NCL) and other two mines (mine 3 and mine 4) belonged to Singareni Coal Company Ltd. (SCCL).

In mine 1, studies were performed on 24/96 Rapier-Ransome draglines working on 30-35 m high sandstone bench and in mine 2 the studies were performed on both 24/96 (Rapier-Ransome) and 15/90 (Russian make) draglines. These two draglines were operating on similar sandstone bench 40-45 m high in vertical tandem. The lower portion of this bench (28-30 m) was worked by 24/96 draglines and the top 15-17 m of this bench was being worked by 15/90 draglines. The OB rocks in these dragline benches of both the mines consisted of medium to

<table>
<thead>
<tr>
<th>Table 1—Productivity factors for dragline as per CMPDI recommendations</th>
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</thead>
<tbody>
<tr>
<td><strong>Particulars</strong></td>
</tr>
<tr>
<td>Swell factor (S)</td>
</tr>
<tr>
<td>Fill factor (F)</td>
</tr>
<tr>
<td>Machine travel &amp; positioning factor (M)</td>
</tr>
<tr>
<td>No. of shifts in a day (N_s)</td>
</tr>
<tr>
<td>No. of hours in a day (N_h)</td>
</tr>
<tr>
<td>No. of days in a year (N_d)</td>
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</table>
coarse-grained sandstone with carboniferous shale and shaly intercalations.

In the mine 3 of SCCL, the OB bench, which was about 30-35 m high, was being worked by 24/96 Rapier and Ransome draglines. The OB rocks of this bench consisted of medium to coarse-grained felspathic sandstone inter-collated at some horizons with thin bands of shale, clay and carbonaceous sandstone.

In the mine 4 of SCCL, the OB bench was worked by 30/92 draglines. This OB bench was about 35-40 m high and it also consisted of medium to coarse-grained felspathic sandstone.

Results and Discussion

Cycle time results

While excavating the blasted muck from one seating position a dragline essentially negotiates varying swing angles at changing instant in order to avoid the frequent marching operation. Hence, for all the five draglines under study, the cycle time observations were conducted at various swing angles encountered during the study. The observations were recorded at swing angles of 45, 60, 90, 120 and even 180 degrees. The segmental cycle time for each segment of total cycle was recorded for these varying swing angles and then the average total cycle time was computed. The total cycle time results for all the five draglines are given in Table 2.

The results from Table 2 reveal that the total cycle time is related to the bucket capacity. With increase in the bucket capacity the bucket placement and digging time segment was observed to increase which, in turn, increased the average total cycle time.

Another noteworthy feature from Table 2 is that the 15/90 dragline of mine 1 the average total cycle time for all the draglines is higher than the standard prescribed norm of 60 s. The increase in total cycle time could be largely attributed to the larger swing angles negotiated by these draglines while operating from one seating position. The swing angles of 120 and 180 degrees were instrumental in inordinate increase in the swing to and swing back segments of operation. It thus appears necessary to properly decide the seating position of draglines in strict accordance to the balancing diagram without allowing for deviations from the stipulated plan.

Availability and utilization results

The results of the field data in terms of SSH, WH, MH, BH and IH for all the draglines as collected from the respective minefields during the study period are given in Table 3.

On substituting the values of useful data in Eqs (1) and (2), the availability and utilization factors have been calculated for all the draglines and the results are given in Table 4.

The results of A and U reveal that barring only 24/96 dragline of mine 1, the values of A and U, are much below the expected standards. The A and U values for large machines like dragline should normally lie in the range of 0.9-0.95 (ref. 3). Earlier studies by Nath and Rai also reported low A and U values for some draglines in the opencast projects of India. It is generally observed in the Indian mining
industry that 80% of the maintenance costs are due to emergency repairs and only 20% are due to scheduled preventive maintenance. It is thus imperative that immediate attention is needed on the maintenance planning of this capital-intensive equipment.

For proper analysis of low utilization of these draglines, an in-depth investigation was carried out to ascertain the potential areas which lead to the unforeseen idling of these machines. Figs 1-5 in the form of bar charts reveal the reasons for loss of available hours and attributes the percentage to each reason. Dozing operations, non-availability of power, blasting operations, non-availability of the blasted muck and other miscellaneous reasons, such as, extended Tiffin hours, shift changeover delays and cable addition/removal are the reasons for poor utilization. Idle time analysis in such a manner assists

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**Fig. 1**—Break-up of idle hours for 15/90 dragline (Mine 1) (A) Dozing Operation, (B) Non-availability of blasted muck, (C) Blasting Operation (D) Cable Adding/Removing, (E) Drag Hatch pin Changing, (F) Site Inspection

**Fig. 2**—Break-up of idle hours for 24/96 dragline (Mine 1) (A) Dozing Operation, (B) Non-availability of Blasted muck, (C) Cable Adding/Removing, (D) Blasting Operation (E) Site Inspection, (F) Drag Hatch pin Changing

**Fig. 3**—Break-up of Idle Hours for 24/96 dragline (Mine 2) (A) Non-availability of blasted muck, (B) Blasting Operations, (C) Site Inspection, (D) Dozing Operation, (E) Non-availability of Power, (F) adopters replacement, (G) Cable adding/removal, (H) Shift Changeover (I) Drag Hatch Pin Changing

**Fig. 4**—Break-up of Idle Hours for 24/96 dragline (Mine 3) (A) Non-availability of blasted muck, (B) Dozing operations, (C) Non-availability of Power, (D) Site Inspection, (E) Blasting, (F) Adaptors Replacement, (G) Drag Hatch Pin Changing, (H) Cable adding/Removal

**Fig. 5**—Break-up of Idle Hours for 30/92 dragline (Mine 4) (A) Non-availability of Blasted muck, (B) Dozing operation, (C) Cable Adding/Removal, (D) Non-availability of Power, (E) Site Inspection, (F) Drag Hatch Pin Changing, (G) Blasting operation, (H) Adaptors Replacement, (I) Shift Changeover
in identifying and subsequently rectifying the potential areas where loss of available hours occurs.

Annual output projections

On substituting the field observed values of average cycle time, A and U and also the other constants (as given in Table 1) in Eq. (3), the annual output (P1) has been projected for all the five draglines. The results of these projected outputs and the prescribed output (P) norms as per CMPDI are given in Table 5.

It is quite evident from the results of the output projections that, barring 24/96 D/L in mine 1 and 24/96 D/L in mine 2, the results in terms of projected output and efficiency of other draglines is not satisfactory. The results for these draglines are below the satisfactory performance levels. Earlier studies by Reddy and Dhar\(^6\) also revealed similar output results in some of the opencast projects of India. Nevertheless, 24/96 dragline in mine1 despite consuming longer total cycle time (69.68 s) yielded slightly efficiency (96.66%) in comparison to similar capacity dragline of mine 2, which consumed shorter cycle time (63.83%) but provided lower efficiency (93.33%). The reason for this discrepancy may be mostly attributed to the availability and utilization factors (as also has been depicted in Figs 2 and 3).

Further from the results of Table 5, it is obvious that the cycle time of 24/96 D/L (mine 3) is almost same as that of 24/96 D/L (mine 2) and cycle time of 30/92 D/L (mine 4) is almost comparable to 24/96 D/L (mine 1). Interestingly enough, 15/90 D/L is operating at the lowest cycle time (56.93 s) out of all the five draglines under the present study. Despite all this the operational efficiency of these three draglines is quite below that of the earlier discussed draglines. This reaffirms the earlier drawn conclusion that, there exists a substantial scope for improvement in the performance of draglines, operated in Indian mines, by improving the maintenance strategies and reducing the uncalled for idling losses. This, in turn, would lead to improvements in the availability and utilization factors to enhance the operating efficiency and the productivity levels.

**Fragmentation versus cycle time**

Improper fragmentation at the collar region poses problems to the dragline bucket, which has to strive and meander a lot to fill the muck from the collar regions. Consequently, the digging segment of the total cycle time was fond to increase enormously as illustrated in Fig. 6 graphically. A perusal of these graphs reveals that the digging time is quite high when the depth of cut is up to 8-10 m. (collar region). As the depth of cut increases, the digging time gets reduced. Tuksuk\(^7\) also reported the influence of blasting efficiency on the digging time of the machines.

During the course of fieldwork it was also observed that during the unloading operation these large collar boulders created problems due to their jamming and interlocking at the mouth of the bucket, which prevented their smooth unloading. This, in turn, increased the unloading time segment, though sporadically.

**Conclusions**

From the present research work following conclusions may be drawn.

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**Table 5—Annual output projections vis-à-vis prescribed output**

<table>
<thead>
<tr>
<th>Mine</th>
<th>Equipment</th>
<th>Cycle time (s)</th>
<th>Projected production (P1) (M.cu.m)</th>
<th>Stipulated production (P) (M.cu.m)</th>
<th>Efficiency (%) (P1/P)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mine 1</td>
<td>15/90 D/L</td>
<td>56.93</td>
<td>1.78</td>
<td>2.25</td>
<td>79.11</td>
</tr>
<tr>
<td></td>
<td>24/96 D/L</td>
<td>69.68</td>
<td>3.48</td>
<td>3.60</td>
<td>96.66</td>
</tr>
<tr>
<td>Mine 2</td>
<td>24/96 D/L</td>
<td>63.83</td>
<td>3.36</td>
<td>3.60</td>
<td>93.33</td>
</tr>
<tr>
<td>Mine 3</td>
<td>24/96 D/L</td>
<td>63.82</td>
<td>2.77</td>
<td>3.60</td>
<td>76.94</td>
</tr>
<tr>
<td>Mine 4</td>
<td>30/92 D/L</td>
<td>69.11</td>
<td>2.45</td>
<td>4.325</td>
<td>56.65</td>
</tr>
</tbody>
</table>

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Fig. 6—Influence of collar oversize on the digging time for different capacity draglines
1 The production and productivity analysis and estimations provide meaningful information on the performance of equipment.

2 The average total cycle time of the draglines is affected by its bucket capacity, swing angle and the seating position.

3 There exists a considerable scope to improve upon the availability and utilization of draglines by improving the maintenance strategies and reducing the unnecessary idling losses.

4 Greater average cycle time and lower availability and utilization of draglines reduces the output capability of these capital intensive equipment. Nevertheless, there is a vast potential for enhancing the productivity by simple and easy methods.

5 Degree of fragmentation affects the dragline performance by increasing the digging segment time and also sometimes by increasing the unloading segment time, though occasionally.

Acknowledgement
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References