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PRODUCTION OPTIMIZATION OF A DRAGLINE BY CYCLE TIME ANALYSIS

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Abstract - *Draglines have been abundantly used in coal mining for decades, either as stripper or coal excavator. Despite its extremely large process a dragline can be said to have a simple routine work which is composed of following procedures: digging and walking.*

Dragline works in a cycle nature. A dragline spends its major operational time by digging the dirt and paying it out on a spoil pile. Dragline cycle time analysis is done in a order to minimize the time taken by the dragline to complete one cycle of operation. Dragline performs thousands of cycles per year. It is evident that small reduction in single cycle time would result in a significant increase in the productivity. Productivity of the dragline increases by optimizing time in dragging, hoisting, swinging. Productivity can also increase by increasing bucket filling factor and desired rock fragmentation.

Key Words: *Dragline, Bucket filling, a Spoil pile, Productivity*

1.INTRODUCTION

Demand on energy is increasing continuously. Coal, which is the most homogeneously spread raw material throughout the earth's crust is among the most demanded fossil fuels. A considerable portion of coal is produced by surface mining methods. Regarding the economics of scale extraction methods are highly mechanized and equipment with huge capacity are utilized. Draglines have been abundantly used in coal mining for decades, either as stripper or coal excavator. As this equipment possess certain inherent advantages, which their rivals do not, they must be operated in a round-the- clock fashion for high productivity and low costs. Despite its colossal posture a dragline can be said to have simple routine of work, which is composed of following basic procedure: digging and walking. Among them walking is a steady process on which the mine design team has little control. Almost all walking draglines take a step of approximately 2 m within a time period of 0.75-1 min. The design of strip panels, equipping a specific unit with one operator's room on the desired side or with two on both sides and the management's strategy in coal loading operation largely affect the frequency and the length of long dead heading periods, during which the unit is unproductive.

The dragline, since its inception many decades ago, is now widely used to economically recover deposits at greater and greater depths. Extremely large draglines are now available with longer booms and higher bucket capacity parameters that go in line with an uprising productivity. Apart from high degree of flexibility, utilization of a dragline results in entirely low costs per cubic meter and subsequent low costs per ton of desired mineral. High initial capital outlay for dragline makes effective and efficient operation to obtain low costs of overburden stripping. Constant supervision, good overburden preparation, and preventive maintenance of dragline and selecting proper bench height of overburden for suitably selected machine should ensure efficient and effective operation of a dragline. Improvement in dragline productivity can have a dramatic effect on overall mining operation. Numerous filed examples have led to believe that with correct application analyses, constant engineering and producing supervision, a dragline can provide an efficient solution to deep strip mining. To say the less, its wide spread application in present mining industry is in sensible more than so ever.

1.1Draglines use in India

Indian mineral industry has contributed significantly to make the nation self- sufficient in coal. To meet the demands of thermal, cement and other users, the production trends in coal and lignite sectors have shown a remarkable increasing trend last few years. While extracting the deep- seated coal deposit and also to increase present production capacity, the coal mines have been compelled to modernize the mining technology, particularly in the fields of blasting.

Coal producers have been already tried to open up big surface coal mines in various coal fields. This has further necessitated the importance of adopting better mining technology in the above mines by applying scientific and economic approaches while selecting the mining equipment and introducing the state-of-the-art technology. In this process it is important to adopt the blasting technology

ISSN- 2394-5125 VOL 8, ISSUE 04, 2021

suitable for the mine as it affects the subsequent operations involved in the mining.
In India, cartridge explosives dominated the surface coal mines until the bulk explosives in the form of slurry and emulsion entered into the explosives market. Since the volume of overburden removal is increasing day by day, the majority of coal sectors have already been switched over to blasting with bulk explosives. As far as the type of explosive is concerned, the coal mines are currently using the slurry or emulsion-based explosives with the gradual exit of NG based form market.
In India, development of large surface mining venturs like Bina and Jayant with setting up of higher coal production targets (10 million tons per annum) calls for systems to remove large volume of overburden in shortest possible time. This has resulted in major changes in overburden/interburden excavation technology in surface coal mines from shovel mining to that of draglines.
Draglines have gained popularity in In India for overburden stripping because of their flexibility and high production rate. Since the faint projects are coming up more in the coal sector in recent times, the shovel mining faces big challenges in fulfilling the production demand. Hence , the Indian surface coal mining has been switching over from shovel mining to dragline mining for removal of overburden in most large sized coal mines to accommodate higb rate of overburden removal and subsequently, high production rate with low cost of production.
The dragline mining was initially introduced in India in early 60's and the first dragline was commissioned at kurashia in 1961. Presently, there are about 43 draglines deployed to remove overburden ranging in bucket capacities from 4 cu.m to about 29-30cu m. Coal India limited (CIL) has now standardized the draglines in two sizes, which are 10/70 and 24/96 for their mines. The economic life of a dragline has been assumed by CIL to be 27 years.
Northern coal fields limited (NCL) is the only subsidiary company of CIL, where the entire coal production is mines by opencast mining methods. Another unique feature of the company is that about 40% of the large volume extraction is done with the help of larger walking draglines. Draglines are used in all mines of NCL except in Jhingurda, kakri and Gobri

1.2 OBJECTIVES

- Literature review on dragline history and present
- System of working of dragline
- Methods of working of dragline
- Draglines used in India
- Time cycle analysis
- Idle time analysis
- Production optimization

2. Methodology

- The specific objectives were achieved by the adoption of following methods
- Critical review of available literature
- Visit to dragline mines for collecting and recording various parameters required for the study

2.1System of working

In a typical cycle of excavation, the bucket is positioned above the material to be extracted. The bucket is then lowered and the dragrope is then drawn so that the bucket along the surface of the material. The bucket is lifted by using the hoist rope. A swing Operation is then performed to move bucket to the place where the material is dumped. The dragline is then released causing the bucket to tilt and empty. This is called dump operation.
The bucket can also be thrown by winding up to the job and then released a clutch on the drag cable. This would then swing the bucket like a pendulum. Once the bucket had passed the vertical, the hoist cable would be released this throwing the bucket. On smaller draglines, a skilled operator could make the bucket land about one-half the length of the job further away than if it had just been dropped. On larger draglines, only few extra meters may be reached.
Draglines have different cutting sequences. The first is side casting method using offset benches; this involves throwing the overburden sideways onto blasted material to make a bench. The second key is a key pass. This pass cuts a key at the toe of the new highwall and also shifts bench further towards the low all. This may also require a chop pass if the wall is blocky. A chop pass involves the bucket being dropped down onto angled highwall to scale surface. The next sequence is the slowest operation, the block pass. However, this pass moved most of the material. It involves using the key to access to bottom of the material to lift it up to spoil or to elevated bench level. The final cut if required is a pull back, pulling material back to low-wall side.

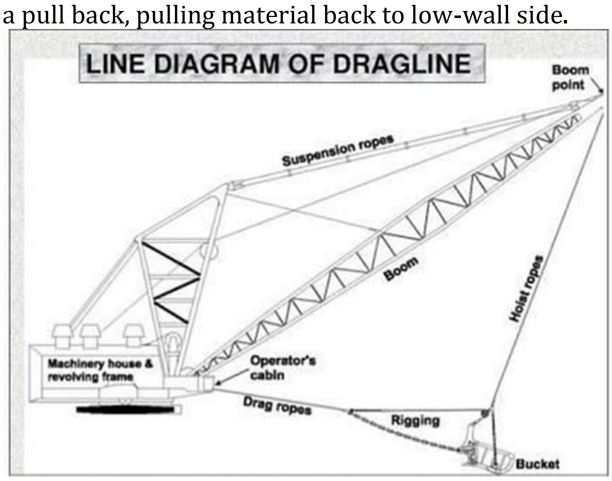

Fig .1 Line diagram of dragline

The operating cycle of dragline consists of basic steps:

- The empty bucket is positioned, ready to be filled.
- The bucket is dragged toward the dragline to fill it.
- The filled bucket is simultaneously hoisted and swung over to the spoil pile. If the swung hoisting to the dump position is completed before the boom is in position to dump, the dragline is said to swing critical.
- The material is dumped on the spoil.

ISSN- 2394-5125 VOL 8, ISSUE 04, 2021

- The bucket is swung back to the cut while simultaneously being lowered and retrieved to the digging position

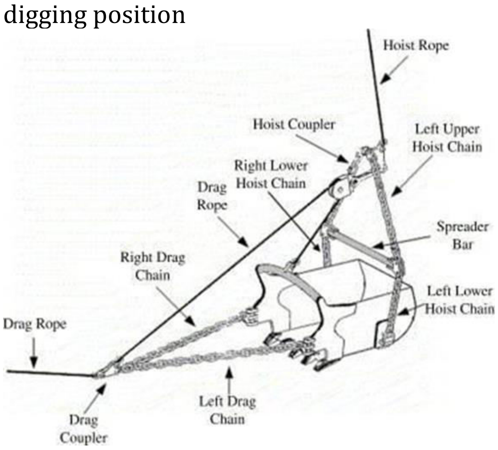

Fig 2.Parts of a dragline bucket

2.2 CYCLE TIME ANALYSIS

The objective of deploying dragline is to remove maximum possible amount of OIB 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 comprises a number of time elements like scooping, swinging, dumping and swinging back time4 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 re leasing the material 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 be low that has been tailored to monthly dragline output

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 de fined as the bank measure of O/B volume moved per period per rated bucket volume. This measure is quite he lpful 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 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 operations7. reduction in bucket cycle ti me, 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 buckets design8. 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 300 to 1800. 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 hi gh 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 pil e, pit configuration, bench height, machine characteristics and operators efficient.

2.3 Idle time analysis

A Close perusal of the bar charts for Bheema dragline as well as for 24/96 dragline, there are five important reasons responsible for idling. These are non-availability of power, dozing operation, blasting operations, idle marching and miscellaneous reasons.

The total Idle hours for Bheema dragline are 60 and for 24/96 are 61. In case of 24/96 dragline 15.4% of total Idle hours is for no power availability and for Bheema dragline is 12.6% of total Idle hours. In case of 24/96 dragline 10% of dozing operations, constitute loss of 11.5% and 17.4 % respectively. For Bheema dragline 9.6% of dozing operations, constitute loss of 10.3% and 15.3% respectively. Previous studies in this direction have also revealed a significant loss in available hours of these HEMM due to =5,18, 131.cu.m

3.0 CASE STUDY AND DATA COLLECTION

The parameters such as bucket capacity, boom length, reach, dumping height, cut width, angle of repose, highwall angle, bench height, digging depth, method of working of two draglines under study were collected and the parameters such as cycle time were recorded from field. The parameters from Bheema mine of scheduled shift hours, average working hours , average Idle hours, average breakdown hours, and average maintenance hours were acquired form

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previous recorded data and those of Singareni OC-3 mines was required from previous field study by Rao.,2017.
blasting operations, dozing operations, tiffin periods and shift changeovers, etc.
Hence, it is imperative at this stage that after analyzing the pertinent reasons for machine idling, the responsibility of

Sl no	Parameters	Details
1	**Dragline(bucket/boom)**	**10/70**
2	**Make**	**Russian**
3	**Max operating radius(m)**	**58**
4	**Bench height(m)**	**35-40**
5	**Cutting width (m)**	**45**
6	**Highwall slope(deg)**	**70**
7	**Bench slope(deg)**	**60**
8	**Angle of repose(deg)**	**38**
9	**Digging depth(m)**	**36**
10	**Reach of dragline (m)**	**58**
11	**Method of working**	**Simple side casting**
12	**Thickness of seam(m)**	**25**

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 clear-cut demarcation of accountability of machine idling can substantially reduce the idling losses by giving forth to a feeling of healthy competition.

2.4 Production Optimization

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 over-burden (OIB) to be removed and the ratio of OIB to coal by volume, (ii) rate of OIB removal necessary to achieve the targeted 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
Production of a dragline can be improved by minimizing each cycle time in order to perform one more operation cycle by using this saved time. Each second of time saved in each operation of the cycle.
Availability of OB at all the time may decrease the Idle hours of a dragline. Bucket filling capacity should be as desired so the OB to be dumped can effectively handle.
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 OIB 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.
Dragline cycle of operation comprises a number of time elements like scooping, swinging, dumping and swinging back time4. 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. So, each second saved in these operations can be used to perform other operation cycle so the availability of optimizing production is more.
Dragline productivity equation=

$$\frac{fill\ factor x bucket capacity}{cycle\ time x swell factor}$$

Fill factor=0.733, bucket capacity=10x1.3=13, cycle

time=66.3 seconds, swell factor=0.719

$$= \frac{0.733x13x3600}{66.3xo.719} = 719$$

Dragline productivity=719x3600x24 hours

Table 1- Productivity factors for dragline as per CMPDI

Particulars	Recommended values
Swell factor(s)	0.719
Fill factor(F)	0.733
Machine travel and positing factor(M)	0.8
No. of shifts in a day ($_{Ns)}$	3
No. Of hours in a day ($_{Nh)}$	8
No. Of days in a year	365

Table 4.2- Parameters of Singareni OCP-3 Dragline

Sl.no	Parameters	Details
1	Dragline(bucket)/boom	24/96
2	Make	Rapier&Ransom
3	Max operating radius(m	88
4	Bench height(m)	30-35
5	Cutting width(m)	60
6	Highwall slope (degrees)	70
7	Bench slope(degrees)	60
8	Angle of repose(degrees)	38
9	Digging depth(m)	25
10	Reach of dragline (m)	73
11	Method of working	Extended bench method
12	Thickness of coal(m)	4.5

ISSN- 2394-5125 VOL 8, ISSUE 04, 2021

Table 3 Parameters of BHEEM Dragline

3.1Projection of annual Output of the dragline Table 4.- Breakup of operational hours

Mine	Equipment	Scheduled shift hours (SSH)	Working hours(WH)	Maintenance hours(MH)	Breakdown hours(BH)	Idle hours
OCP-	24/96	720	507	119	33	61
Bheema	10/70	720	540	90	30	60

Table 5-The average total cycle time results

Mine	Equipment	Standard cycle time(s)	Observed cycle time(s)
Singareni OCP-3	24/96	60	61.7
Bheema	10/70	60	66.3

Table-5 Availability and utilization factors

Mine	Equipment	Availability factor	Utilization factor
Bheema OCP-3	24/96	0.7888	0.7041
Bheema	10/70	0.8333	0.75

5RESULTS

- The projected monthly Output of the BHEEM Dragline is 0.518M cu cu.
- Dragline operating cost per meter cube overburden handle considering annual Output of Singareni OC-3 dragline (24/96) as 2.807 M cu. m is rs. 81.67.
- Dragline operating cost per meter cube over burden handle considering annual Output of BHEEM dragline (10/70) as 1.253M cu.m it rs 82.2
- Estimated cost/tonne of coal exposed by Singareni OC-3 dragline (24/96) is rs 285.78
- Estimated cost/tonne of coal exposed by the BHEEM dragline {10/70) is Rs. 247.17.

6. CONCLUSIONS

- 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.
- There is a great variation in scooping time. However, improved bucket design and proper blasting practices can reduce scooping time.
- Idling of dragline should not be tolerated even for a few seconds as it leads to depreciation and production losses.
- Idling hour distribution of draglines has thrown sufficient insight into the reasons primarily responsible for machine idling in the field operating conditions.
- Non availability of power appears to be one of the major bottlenecks in dragline performance. Hence, power availability in mines must be given attention

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