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Optimization of shovel-dumper combination in lignite mine: a case study

In the open pit mines, to have better productivity the requirement of large equipment is inevitable. Due to the huge investments involved, no mine can afford to have loss in investment then its equipment inefficient work, increased the idle time of equipment. Shovel-dumper combination is the most preferred one in surface mining. Therefore, capacity of shovel and dumper should closely match with each other. In surface mining operations, truck/dumper haulage contributes maximum towards operating costs, accounting for 50 to 60% of the total. To control the same, it is necessary to align the shovel with dumper/truck. Shovel-truck combination is the most sought and effective in small as well as large-scale mines, especially in Indian mines. The optimization of shovel-truck combination is essential in order to increase productivity of mine. Optimization studies aim at eliminating the excess number of shovel or dumper in order to minimize the total cost, incurred. This paper describes shovel and truck operation optimization approaches, done on real time basis. A case study in this regard done in one of the lignite mines of India.

Keywords: *Equipment, idle time, shovel, dumper, optimization.*

Introduction

In a typical surface mining operation, material-handling system is composed of three phases i.e. loading, hauling and dumping subsystems. Effective and efficient materials handling systems can only be possible if these three phases perform in sink [2, 7]. Transport of material (ROM) from production faces to dumping sites is done with the help of rail, truck or belt conveyor. Out of all available techniques, shovel-truck systems are most common in open pit mining.

The types of loader and excavator selected for use in a surface mine depends on the type and nature of mineral to mined and specifications of the environment, such as the bench height [4]. Other factors, which need attention, are compatibility of the loaders with dumper fleets i.e. the capacity of both should match with each other.

The most important factor in every operation is profitability. Productivity of equipment used is an important factor of profitability. Profitability can increase by optimization of the equipment combination used. Therefore, the first goal in these optimization techniques is to maximize productivity, which in turn will result in cost reduction [6]. For shovel-dumper operations, the target is to achieve minimum unit cost per unit volume of material. When the cost is of prime importance, Trade-off is sought between the cost of idle time of the shovel and the cost of providing extra trucks, when cost incurred is the main concern.

An open pit operation is considered to consist of four phases i.e. loading (done by shovel), hauling (by loaded dumpers), dumping (by dumpers at dumping site) and return of empty dumpers. For a particular mine, loading location may be any part of the mine where there is availability of material, such as pit locations where primary excavations occur and stockpiles where material is temporarily stored. Similarly, dumpling destinations include processing locations (including crushers), stockpiles and waste dumpsites. However, these multiple locations of loading and dumping very often lead to the complications of equipment performance [1, 3]. Since there may be several loading locations with different loading requirements, different loader types may be required. The selected trucking fleet must be compatible with the loaders assigned in each period. This issue of compatibility is a complicating characteristic of surface mining equipment selection, since the trucking fleets may switch task assignments from period to period [2, 5].

Methodology

The proposed work carried out for mine for the year 2017-18 depending upon the machinery utilized there for production purposes. The production of the mine for this year was 0.3 million tonnes against the target of 1 million tonnes due to poor fleet management.

(I) NO OF DUMPER REQUIRED FOR 0.3 MILLION TONNE (LIGNITE) PRODUCTION PER YEAR

Cycle time of dumper = 12 min. No of trip in 1 hr = 5

Total working days in mine in a year: 365-52-11 = 302

Total working hours in a year: 302*16 = 4832 (as the mine works only in two shifts)

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TABLE 1: VARIOUS MACHINERIES DEPLOYED AT MINES

	Type of machine	Make	Volume Capacity	No's Units	Cost of 1 unit	Total cost
			Excavator/shovel			
1	Volvo-480	Volvo	3.1 Cum	4	92 lakh	3.68 cr
2	Volvo-290	Volvo	1.4 Cum	1	44 lakh	0.44 cr
3	Kobelco-210	Kobelco	1.1 Cum	2	62 lakh	1.24 cr
			Dumpers			
4	Dumper-volvo	FM-440	18 Cum	6	54 lakh	3.24 cr
5	Dumper	Bharat benz	18 Cum	13	27 lakh	3.51 cr
			Support services			
6	Motor grader	SDLG	NA	1	43 lakh	0.43 cr
7	Dozer-39 Ex	Komatsu	NA	1	68 lakh	0.68 cr
8	Water tanker	Tata	20KL	1	26 lakh	0.26 cr

Total equipment cost: INR 13.48cr (appox)

Production hours for dumper: 4832* 0.606 = 2928.19 hrs

Capacity of dumper = 18 cu.m. = 18×1.8 = 32.4 Tonnes

OEE of dumper = 0.85*0.75*0.95 = 0.606

Production hours for dumper: 4832* 0.606 = 2928.19 hrs

Total tonnage in one year by 1 dumper = 32*2928.19*5 = 468,510 tonne/0.47 million tonnes

No. of dumpers required for 0.3 million tonnes = (total production/production by 1 dumper) = 0.3/0.47 = 0.63

Actual requirement = 0.63/ Mechanical availability = 0.63/ 0.85 = 0.75 = Around 1 dumper.

(II) NO. OF DUMPER REQUIRED FOR OVERBURDEN

Stripping ratio of mine is 1:15

Total overburden for 0.3 million tonnes = 4.5 million cu.m. (o/b is considered in cu.m)

Total capacity of dumper in 1 year = Dumper capacity * Production/year* no. of trips per hour

= 18*2928.19*5 = 263520 tonnes = 0.26 mts

No. of dumpers required = 4.5/0.26 = 17.3, therefore around 17 dumpers are required.

Total no. of dumpers = 17 for overburden and 1 for lignite extraction = 18 in total

(III) NO. OF SHOVEL REQUIRED FOR OVERBURDEN

Capacity of shovel bucket: 3.1 cu.m. overburden = 4.5 cu.m.

1 pass = 20 sec; 180 passes in 1 hour material filled in 1 pass = 3.1*0.8 material filled in 1 hour = 3.1*0.8*180

OEE of shovel = 0.85*0.75*0.95 = 0.606

Material filled in 1 year = 3.1*0.8*180*4832*0.606 = 1.3 million tonnes.

Shovels required = 4.5/1.3 = 3.46/.85 = 4.07 = 4 shovels

(IV) NO. OF SHOVEL REQUIRED FOR LIGNITE EXTRACTION

Capacity of shovel bucket: 3.1cu.m.*1.8 = 5.58*0.8 = 4.46 tonnes. 1 pass = 20 sec; 180 passes in 1 hour

Material filled in 1 pass = 4.46 tonnes

Material filled in 1 hour = 4.46*180

Material filled in 1 year = 4.46*180*2928.19 = 2.3 million tonnes

No. of shovels required: 0.3/2.3 = 0.13/0.85 = 0.15

Therefore, one shovel of bucket capacity 3.1 cu.m capacity is enough for 0.3 million tonnes of lignite production.

Total no. of shovels = 4 for overburden and 1 for lignite extraction = 05 in total as mentioned in Table 1, the mine is using 19 dumpers and 7 shovels.

Conclusion

The required no. of dumpers and shovels for production of 0.3 million tonnes lignite is l8 and 5 respectively for the work being done in 2 shifts. In contrast, the mine was using 19 dumpers and 7 shovels. Therefore, if fleet management would be proper, cost of 1 dumper and 2 shovels can be reduced and subsequently the man power required for it.

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