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Improvement of overall equipment performance of underground mining machines- a case study

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ABSTRACT

Production and productivity of any industry mainly depends on effective utilization of men and machinery. Underground mine production for the last few decades in India is not in satisfactory level, due to less mechanization. The maximum amount is expended for introducing the large scale mechanized equipment. Hence, mechanization in loading system has made advantageous towards production. In spite of this Load Haul Dumper (LHD) is one and used as loading and hauling machine for intermediate of operation. During the operation of the equipment, possible major breakdowns are occurred in some aspects. Therefore, these lead to reduce the percentage availability and utilization of the machines. As a result of this, it is very essential to analyze the performance of LHD machines, to reduce the cost during the operations. The higher availability of machine gives an optimum utilization, which increase the production and productivity of these principal intensive items. Keeping this in view, this paper focuses on improvement of overall equipment performance (OEP) by calculating the percentage availability and capacity utilization of LHDs in underground mines. Further an attempt is also emphasized to identify the contributing factors of performance improvement.

1. INTRODUCTION

Performance of the equipment can be determined in many ways. The overall equipment performance (OEP) of the machines are mainly depends on its effective utilization. Non-availability of machines in its working face and its in-effective utilization causes a harsh reduction in production levels and mine production costs. Producing of projected level minerals in a stipulated period of time is mostly depends upon proper utilization of equipment and their consequences [1]. OEP can also be defined as the ratio of produced output to the utilized resources. Produced output can be taken in many ways based on the requirement and is expressed as daily basis, monthly basis and yearly basis. During the equipment analysis these values are taken as an average value for era of considered period. Expected levels of production in any large/small scale mines can be enhanced by converting non-mechanized into well-established mechanized mines and by maintaining these in most efficient and effective manner [5-6]. Availability and utilization are the key performance indicators of equipment and measurement of its OEP is a standard tool for management at the time of decision-making in the mine operations. As in [7-8] and [6], Improvement of production rates, equipment's availability and its consequent performance are very case sensitive in any kind of industries. The capacities of these are controlled by various influencing factors. Therefore, improvement of OEP is very essential and can be improved by proper measurement of equipment's availability and its capacity utilization factors.

2. INLUENCING FACTORS OF PRODUCTIVITY

Table 1. Records of essential data

Parameter	Implication	Value/Cause
Annual Calendar Hours (ACH)	Available number of hours for a period of observation.	365 days × 24 hours = 8760 hours in one year. (These may vary Statutory holidays and manufacture defects)
Total Shift Hours (TSH)	Whole number of hours in a year during observation (SSH+AMH+MWH)	26 × 24 × 12 = 7488 hours
Scheduled Shift Hours (SSH)	Number of hours planned by the management that the equipment is supposed to work to perform its specified task in the mine premises.	24hrs×6days×4weeks×12months =6912hours/Annam
Available Machine Hours (AMH)	Number of hours that machine or equipment is available at its work face to perform the specified task within its SSH. (MWH+MIH)	proper maintenance of the equipment, ensuring of spare parts availability and skill of the operating screws
Machine Working Hours (MWH)	Effective number of Machine worked hours. (MWH= Available hrs-Actual hrs)	Lack of co-ordination, non-availability of blasted ore, spare parts, ground engaging tools and change of operations

In underground mining operation wide variety of parameters are affecting to the productivity, the major influencing parameters are listed below in both machine and mine related [3]:

Machine related problems such as breakdown of LHD, poor performance of LHD, improper maintenance and increased cycle time: which involves both machine loading, travelling and dumping time. These hours will reflect on the operational and production costs of the machine.

Mine related problems such as breakdown of drill machine, lack of sufficient blasted ore, improper blast round design, uneven path (road) condition, inaccurate wedge cut formation, inadequate stemming, improper delay mechanism, improper connection, breakdown of conveyor, improper lead distance, fragmentation, improper ventilation, electric faults and power tripping, roof problems.

In order to perform the analysis of the equipment the required records are supposed to be collected and maintained over an era of time. These records will present a comprehensive idea of failure characteristics of the machine. The collected data includes equipment's failure type, cause of failure, failure occurring time and repair or restore time after correction. In addition to that it is very essential to maintain the records from up- to-date [2] and shown in Table.1

3. CASE STUDY

The case study has been carried out in one of the Indian underground coal mine of southern region. The colliery is currently being operated in Seam 4 and Seam 6 employing the bord and pillar method. Coal extraction in underground mine is done by drilling and blasting, and the extracted coal is transported from mined out place to required place through intermediate level mechanized systems. LHDs are one used as the main work horse for coal transportation. The function of the equipment is made to perform the specified task i.e., load, tram and dump the coal in the mine. A schematic representation of typical LHD machine in a blasting gallery is shown in Figure 1.

Figure 1. Typical LHD machine in a blasting gallery mine

4. RESULTS AND DISCUSSION

After identifying the influencing parameters of productivity, it is necessary to determine the performance of equipment by calculating percentage availability, capacity utilization, production efficiency and overall efficiency with collected information from the mine. The month wise details regarding maintenance hours, breakdown (Hydraulic, Electrical and mechanical) hours, working hours and idle hours of two different LHDs have been collected and analyzed for a year. Collected data of maintenance profile and production profiles are shown in Table.2.

where, SSH indicates Scheduled Shift Hours, MH is Maintenance Hours, HBH is Hydraulic Breakdown Hours, EBH is Electrical Breakdown Hours, MBH is Mechanical Breakdown Hours, WH is Work done Hours and IH is Idle Hours.

4.1 Percentage Availability (PA)

It is defined as the available percentage of machine to perform its specified task at its working face. PA of machine may also be defined as the ratio of AMH to the shift scheduled hours. While calculating the percentage availability SSH is taken as total TSH for a period considerable period of equipment's operation. If any extra hours of work beyond the shift are existed, these can be added to the TSH. The idle period of less than or equals to 15 minutes can be ignored. PA also facilitates the information for effectiveness or efficiencies of different maintenance practices. This information is an added value to the management to knowing the how machine availability would vary by varying the scheduled shift hours.

$$PA = \frac{AMH}{SSH} \text{ Or } \frac{AMH}{TSH} \quad (1)$$

4.2 Capacity Utilization (CU)

CU can be defined as the ratio of working hours of the machine to its actual utilized hours in the work environment. It also defined as the ratio between machine working hours to its scheduled shift hours, total shift hours and machine available hours. Depending upon these denominator values the quantity of capacity utilization is varied. As in observation available machine hours are always lesser than scheduled shift hours and capacity utilization percentage.

$$CU = \frac{MWH}{TSH} \text{ or } \frac{MWH}{SSH} \text{ or } \frac{MWH}{AMH} \quad (2)$$

4.3 Production Efficiency (η_{PE})

$$\eta PE = \frac{\text{Actual O/P}}{\text{Target O/P}} \times 100 \quad (3)$$

Production efficiency is defined as the ratio of actual production to its target production of the equipment. The value of production is taken into account as an hour or per shift or per a year. It also defined as the product of operating efficiency and the job management efficiency of machine or equipment. Operating efficiency of equipment is defined as the ratio of operating capacity to its rated capacity. Job management efficiency provides relationship of internal, external and environmental factors. Internal and external factors are system and sub-system’s components. Environment factors are equipment’s working environment and mine operator skill etc. CMPDI standards of equipment’s percentage availability and capacity utilization, production efficiency, job management and overall efficiencies are used in most of mining conditions shown in Table.2.

Table 2. Collected data of LHD-9 & LHD-12 for the year 2015-16

Machine	Maintenance Profile (Hrs)							Production Profile (T)	
Parameter	SSH	MH	HBH	EBH	MBH	W H	I H	Target	Achieved
LHD-9	7392	1314	194	179	284	4002	1610	6520	5322
LHD-12	7392	1334	245	203	364	4060	1197	6424	6424

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Table 2. CMPDI Standards of mining conditions for equipments (Source: [2])

PA and CU	Production Efficiency	Job Management Efficiency	Overall efficiency	Remark
100%	95%	95%	90%	Excellent
90%	85%	85%	80%	Good
80%	75%	75%	70%	Average
70%	65%	65%	60%	Fair
60%	55%	55%	50%	Poor

When an LHD machine is treated as individual equipment i.e. performing the operations of both loading, hauling and dumping itself, production efficiency will be equal to efficiency of equipment. In underground mines when an LHD machines are used as coal transportation system, both operating efficiency of equipment and job management efficiency are taken into account.

4.5 Overall efficiency (η_{OE})

Overall efficiency is the product of CU based on AMH and Production Efficiency of subjected machine or equipment. It is the overall measurement of equipment's performance and which will provide complete information on machine to the management. The quantity of overall efficiency cannot be varied by changes in recording the time factor, such as production efficiency with less operating time and capacity utilization percentage with more operating time.

$$\text{Overall Efficiency } (\eta OE) = CU(AMH) \times \eta(PE)$$

Machine availability and its utilization percentage factors of LHDs are quantified through TSH, SSH and AMH basis. Independent efficiencies of both production and overall efficiencies were also calculated using total achieved production with respect to the target for one year, Shown in Table.3.

Table 3. Availability and Utilization factors of LHDs for the year 2015-16

Parameters	Machine	
	LHD-9	LHD-12
Total Shift Hours (TSH)	7488	7488
Shift Scheduled Hours (SSH)	7392	7392
Machine Maintenance Hours (MMH)	1314	1334
Machine Breakdown Hours (MBH)	675	812
Machine Repair Hours (MRH)	655	798
Available Machine Hours (AMH)	5612	5257
Machine Worked Hours (MWH)	4002	4060
Machine Idle Hours (MIH)	1610	1197
Percentage Availability of TSH (%)	74.94	70.20
Percentage Availability of SSH (%)	75.91	71.11
Capacity Utilization of TSH (%)	53.44	54.22
Capacity Utilization of SSH (%)	54.13	54.92
Capacity Utilization of AMH (%)	71.31	77.23
Target Production in Tonne	75,250	75,250
Actual Production in Tonne	51,035	44,809
Productivity in Million Tonne	3,436	2,826
Production Efficiency (%)	67.82	59.54
Overall Efficiency (%)	48.34	45.95

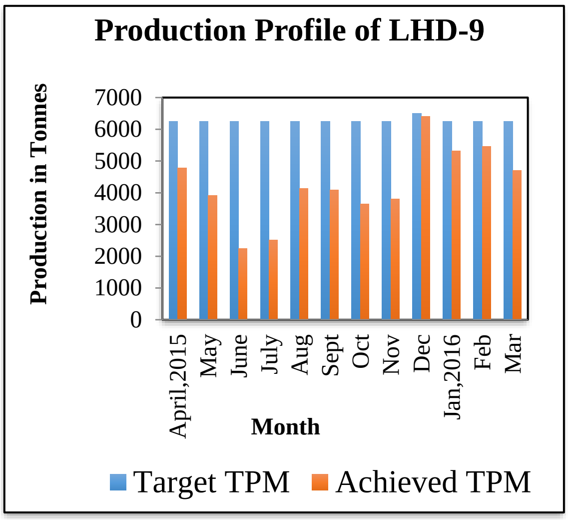

Figure 2. Production Profile of LHD-9 in TPM

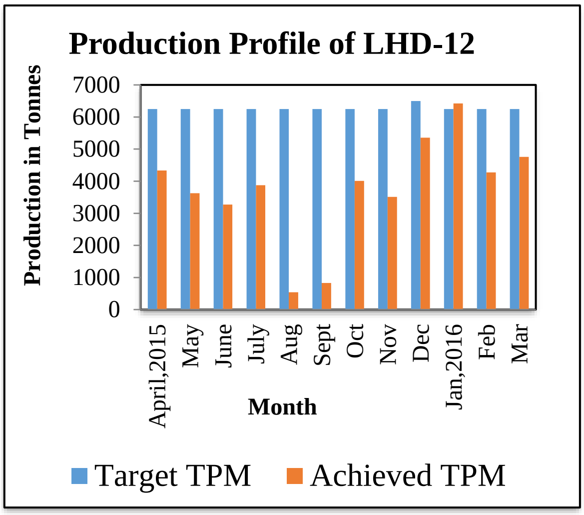

Figure 3. Production Profile of LHD-12 in TPM

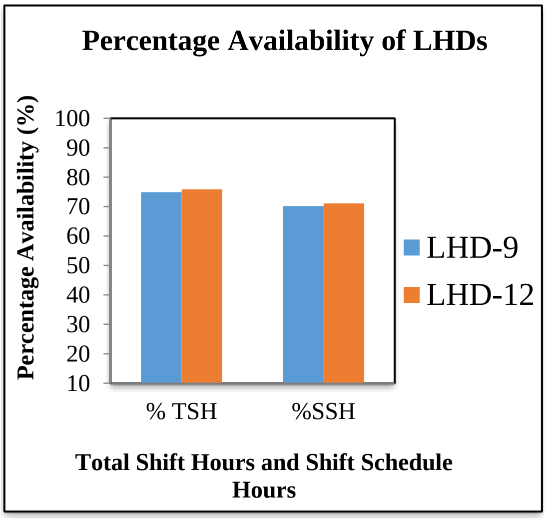

Figure 4. Percentage Availability of LHDs in Hrs

Comparison of each individual factor of LHDs has been made through plotting the respective graphs. Production scenario of LHDs on monthly basis for one year is shown in Fig 2 and Fig 3 intones. Machine availability and its utilization percentage of LHDs on the basis of TSH, SSH and MAH are shown in Fig 4, and Fig 5 respectively and its overall efficiency is shown in Fig 6.

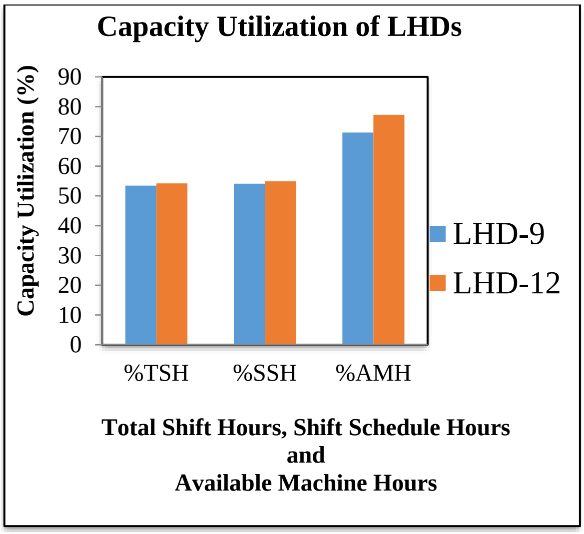

Figure 5. Capacity Utilization of LHDs in Hrs

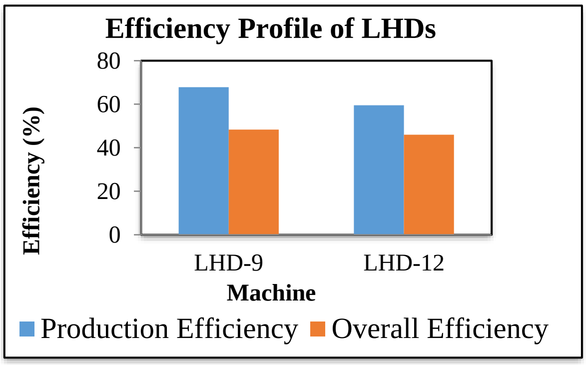

Figure 6. Efficiency profile of LHDs in percentage

The values of machine availability and its utilization percentages and resulting efficiencies were given in Table.4. Comparisons of these values were made by the CMPDI standards and are given in brackets.

The findings of the present investigation show that machine available hours are very less as compared with its total shift hours. The values of MA for LHD-9 and LHD-12 on the basis of SSH are 75.91%, 71.11% and its consequent CU are 54.13%, 54.92%, which are far below normal. The achieved production figures of the LHD vehicles are 51,035Tonnes, 44,809Tonnes and projected target for both is 75,250Tonnes. As a result of these values, it can be understood that the productivity of LHDs are not satisfactory and are not reaching to the expected targets of production.

The values of machine availability and its utilization percentages and resulting efficiencies were given in Table.4. Comparisons of these values were made by the CMPDI standards and are given in brackets.

Where, MA denotes machine Availability, UP is Utilization Percentage.

Percentage distribution of TSH and SSH of LHDs for an era of period are shown in Table.5 and Table.6. Percentage distribution of scheduled hours such as MMH, BH, MWH and IH were shown in Fig.7 and Fig.8 respectively.

Table 4. Comparison of LHD parameters with CMPDI standards

Machine ID	MA on SSH Basis (%)	MA on TSH Basis (%)	UP on SSH Basis (%)	UP on TSH Basis (%)	UP on AMH Basis (%)	$\eta_{Prod.}$ (%)	$\eta_{Overall}$ (%)
LHD-9	75.91 (80)	74.94 (80)	54.13 (50)	53.13 (50)	71.31 (70)	67.82 (75)	48.34 (50)
LHD-12	71.11 (70)	70.20 (70)	54.92 (50)	54.22 (50)	77.23 (80)	59.54 (65)	45.95 (50)

Table 5. Percentage distributions of TSH for the year 2015-16

Particulars	Machine		
	LHD-9	LHD-12	Average
	% of Hours	% of Hours	% of Hours
Unscheduled hours	14.00	14.00	14.00
Unavailable hours	12.00	16.00	14.00
Unutilized hours	21.00	16.00	18.50
Utilized hours	53.00	54.00	53.50
Total	100.00	100.00	100.00

Table 6. Percentage distributions of shift scheduled hours for 2015

Particulars	LHD-9		LHD-12		Average	
	Hrs	% of Hrs	Hrs	% of Hrs	Hrs	% of Hrs
Machine Maintenance Hrs (MMH)	1314	17.00	1334	18.00	1324	17.50
Machine Breakdown Hrs (MBH)	657	08.00	812	11.00	734.5	09.50
Machine Worked Hrs (MWH)	4002	54.00	4060	55.00	4031	54.50
Machine Idle Hrs (MIH)	1610	21.00	1197	16.00	1403.5	18.50
Total	7583	100.00	7403	100.00	7493	100.00

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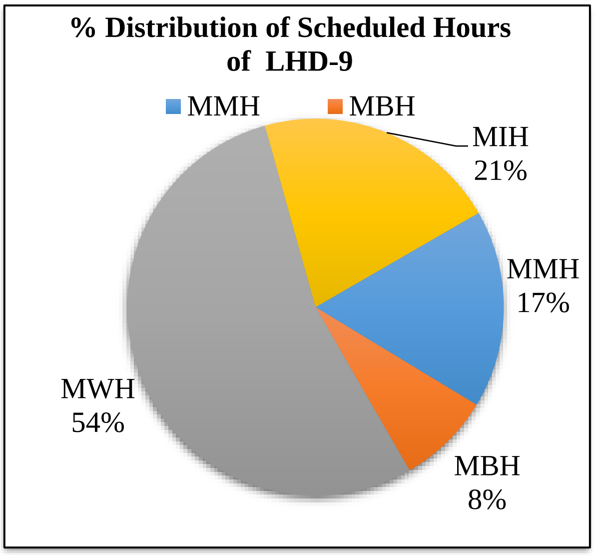

Figure 7. Percentage distribution of scheduled

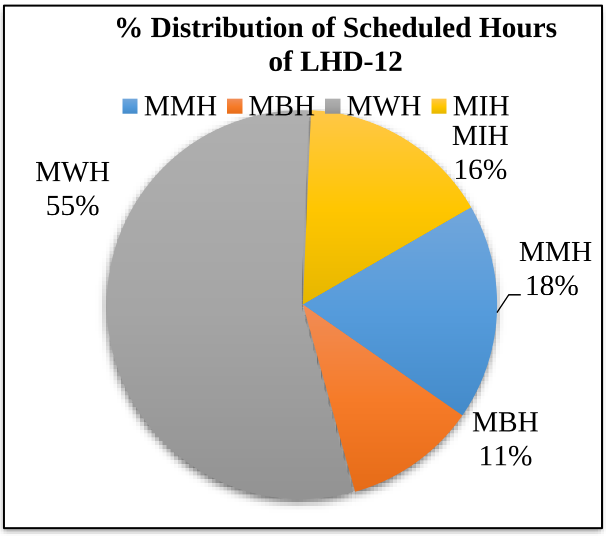

Figure 8. Percentage distribution of scheduled hours of LHD-9 hours of LHD-12

Therefore, the management has to take a decision for introducing the measures to improve the equipment's availability and its effective utilization. Improper maintenance practices are the main causes for frequent breakdowns of the machine during its operation. These practices will impact on machine available hours. It can also be identified that there is a huge time gap between machine failure hours to its repair hours which shows that in-effectiveness of maintenance organization by the management. Job management efficiency is another factor for machine utilization and it can be improved by unscheduled hours are planned into scheduled hours. It was noticed that the production efficiencies of LHDs are 67.82%, 59.54% respectively and are in satisfactory level, however overall efficiencies are very less and represented as 48.34%, 45.15% which indicates that there is lack of team work.

5. RECOMMENDATIONs

Underground mine production is influenced by vide variety of parameters. There was a need in all the time for improvement of production levels and its consequences. The following measures required to be adopted to enhance LHD performance.

- It is recommended that the availability of the machines will be improved by reducing the downtimes through strict adherence of preventive maintenance schedules.
- Machine breakdowns are minimized or reduced by conducting daily maintenance practices before starting of the machine and by ensuring suitable requirements of skilled operators.
- Better organization of men and machinery by the management will increases the team endeavor.
- In-active hours or machine idle hours of the equipment are reduced or minimized by start the machine or operation to its work face without any time delay. To perform this operation skilled machine crew and well maintained equipment are essential.
- Efficient working of the machine can be obtained by increasing the available machine hours in a planned shift. Machine availability and its percentage utilization are increased by an approximate value of 25% through adoption of shift overlapping.

6. CONCLUSION

Percentage availability and capacity utilization studies are helpful to measure the performance of equipment in any mining industry. These studies can also provide the necessary recommendations to mining industry for further improvement. From the above studies various phases have been considered to improve the machine availability and utilization percentage of LHDs. As a result of this the production and productivities are improved and its corresponding performance of the equipment is increased. If the above measures are well practiced, underground mining methods are assured to produce required levels of production and to meet the power requirement of the country.

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