A CRITICAL STUDY ON AVAILABILITY AND CAPACITY UTILIZATION OF SIDE DISCHARGE LOADERS FOR PERFORMANCE ASSESSMENT

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Abstract

Improvement in production and productivity has become an important aspect for today's coal industry especially in case of underground coal mines. The record of production and productivity of Indian underground coal mines over the years is dismal, to say the least. Mechanization in loading system has made possible major breakthroughs in underground coal mining technology. Side Discharge Loaders (SDL) is now used as a loading machine for intermediate mechanization in underground coal mining. To meet the production and productivity issues the SDL machine should be maintained effectively and efficiently to have maximum availability. Higher availability of machine shall enable optimum utilization thus increasing production and productivity of these capital intensive items.. This paper intends to identify and highlight the various factors and problems affecting performance of SDL machine. Further an attempt is made to calculate the percentage availability and utilization of SDL deployed in underground coal mines and analyzes the contributing factors to improve the overall efficiency. In addition, the problems of SDL application, breakdown and its management have also been identified and resolved in these studies to propose suitable measures for improving them.

Keywords: *Side Discharge Loaders, performance, assessment, scheduled hours, maintenance hours, available hours, percentage availability, percentage utilization, production efficiency, operating efficiency, management efficiency, overall efficiency.*

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1. INTRODUCTION

Coal mining in India has a history of over 235 years. The industry currently occupies a covetable third place in world coal production after China and USA with a 10% share of total global coal production after the countries like China, USA and Australia are about 95, 33 and 20% respectively. India produces about 10% of coal from underground mines. At the time of nationalization (1971) of the coal industry, contributions of national coal production by underground and opencast mines were 77.45% and 22.55% respectively. By 2010-11, the share of coal production by different underground methods may be stated thus Bord and Pillar method - (34.10% conventional, SDL/LHD – 55.90% mechanized), Longwall – (conventional-0.60%, mechanized – 7.80%) and other methods – 1.60%.

Of the total output of coal from underground mines, more than 90% of the coal is obtained by the Bord and Pillar method, the popular method of mining in followed in India and the rest by Longwall mining method. The Indian coal mining industry has witnessed a persistent decline in Underground coal production over the years with more emphasis on opencast mining. Coal Production trend is shown in Fig 1.

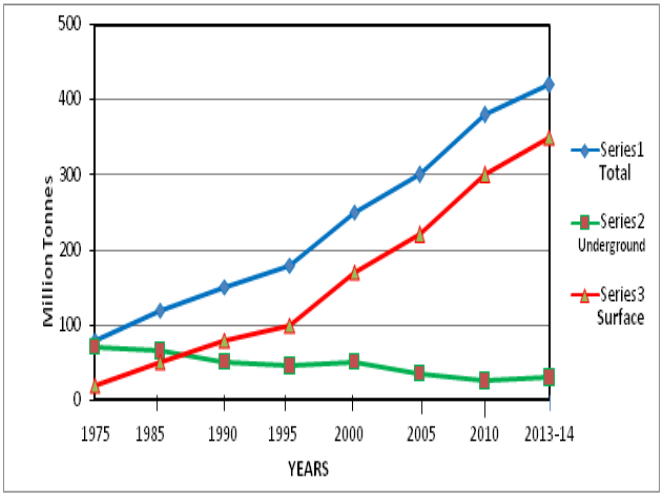


Fig 1. Trend of coal production from CIL mines (1975 to 2014)

A new principle of side dumping front end loading for underground mucking machines has completely changed the concept of underground loading and haulage equipment arrangement both in production and development work loading. Versatility and adaptability of this type of machine permits combinations with a broad range of haulage means not possible with -conventional overhead loaders. Chain conveyors serving this type of loader are replacing

conventional rail mounted car haulage to give a continuous loading operation and effect important economics of reduced manpower, faster loading rates and fewer working areas for a required production. First used in Germany this easy to control and highly efficient means of placing rock from the muck pile on or into haulage means has advanced the art of underground rock loading more in the past three decades than any other advancement since the first successful small crawler mounted air powered loader was introduced in 1954. Bucket type loaders with a relative new side dump principle are gaining in popularity for underground loading. They are replacing conventional overhead loaders in present applications and becoming first choice in new ones. Primarily meant for hard rock development and production loading they are also widely used in production loading of coal and other soft materials. [1] This discussion briefly traces the historical development of underground loaders to the new side dump type and its present population. In more detail various applications, loading techniques and the advantages of operation, production and economy with the side dumper in coal loading will be dealt with. The productivity of a mine can be improved by increasing the level of mechanization, introduction of state-of-the-art machines and ensuring their optimal utilization as per international standards, proper inventory management, reduction in cost due to accidents through improved health and safety standards, improved work culture and discipline through efficient management.

The grim scenario of underground coal production along with the likely exhaustion of shallow depth coal reserves and problems faced regarding surface land acquisition for opencast mining have warranted a quantum jump in coal production and productivity from underground mines in India. This paper mainly focuses on improving the efficiency of various operations carried out during the coal extraction process for improving productivity of underground coal mines. Three innovative methods for side discharge loader (SDL) cable handling which will lead to a significant increase in the productivity have also been proposed in this paper. In order to meet the coal demand, a number of actions are being taken by mining companies to increase production from the existing mines and through the introduction of new technologies.

The mechanization trend in the bord and pillar method of coal mining introduced sophisticated automated side discharge loader (SDL) / load haul dumper (LHD) machines for loading of coal in place of manual loading. Among the face loading machines, the electric SDL is now the dominant machine as intermediate technology in underground mines and plays an important role in district or overall mine production. To achieve targeted coal production and to survive the intense competition in the mining industry in recent years, it is imperative that an SDL machine as a system and its subsystems should be reliable and maintained effectively and efficiently to ensure its maximized availability and utilization.[2]

2. PRESENT STATUS

Coal India Limited, because of its improved performance on an overall basis has got the Maharatna Status, however the performance of its underground mines has largely been unsatisfactory with a few exceptions in one or two subsidiary companies. Majority of its underground mines are making losses. However, some of the underground mines of Eastern Coalfields Limited (ECL), Bharat Coking Coal Limited (BCCL) and Central Coalfields Limited (CCL) are not amenable to total mechanization due to geo-mining conditions that are not conducive to mechanization and a consequential sub optimal level of evacuation capacity.

The overall coal production is below the target from underground mines of CIL. Relatively better performance in the SECL mines are observed because of the already existing Side Discharge Loaders and Load Haul Dumpers technology in most of the mines. Conditions are worst in BCCL and ECL mines where SDL and LHD with conveyor are yet to be introduced in most of the underground coal mines. Losses in underground mines is essentially due to lack of modernization, labour intensive technology, old and deepening mines with difficult geo-mining conditions and increasing cost of mining day by day. Further strengthening the need for introduction of mechanized coal getting methods capable of giving better production and productivity should be arrived at.

While addressing production and productivity scenario for their substantial improvement, it is essential to keep in mind the better environmental with the present and eco-friendly status of this method, vis-a-vis, and Open Cast mining. This is further emphasized by the fact that the workable seams in most of the mines getting increasingly deeper and in a decade or so may go beyond the economic stripping limit notwithstanding the development in the reach and capacity of the open cast excavators. Environmental impact of opencast mining is a growing concern in view of expected green and clean mining.

The minister of state (Independent Charge) for Coal informed the Lok Sabha recently that most of the mines of Coal India Limited are either fully mechanized or semi-mechanized. Giving details about the technology up gradation of the mines, the minister said, the thrust areas for the future may remain the Bord and Pillar method with higher degree of mechanization like continuous miners technology in conjunction with mechanized drilling and roof bolting system.

(Steps to increase Coal Production from Underground Mines, Published: Saturday, 02 August-2014)
Raw coal production in India during 2013-14 in CIL & its subsidiaries and in SCCL was 462.42 and 50.47 million tonnes respectively. 9% of the coal produced is from the underground mines.

The following steps have been taken by Coal India Limited to enhance underground production:

- Gradual conversion of manual underground mines into semi mechanized technology like Load Haul Dump (LHD) / Side Discharge Loader (SDL) with Universal Drilling Machine (UDM).
- Mass Production Technology i.e. use of Continuous Miner and Long Wall Technology, development in transport infrastructure.
- Deployment of 7 Continuous Miners with a capacity of about 2.835 Mty. Further, Project Report for 20 mines has been approved for deployment of 25 Continuous Miners with total capacity of 11.385 Mty.
- Orders have been issued for operating five mines with long-wall technology.

In SCCL, the following steps have been taken:

- One underground mine with new generation Long wall Technology is under construction designed for rated production of 2.81 MT.
- Three new underground mines (all with Continuous Miners) are planned to start production against nine UG mines likely to be closed during XII plan.
- Reconstruction of existing mines for optimum production by intermediate and high-end technology.
- Improving the productivity in the existing mines **by improving the utilization of the equipment.**
- Exploration for new coal blocks has been expedited.

Table 1 Coal Production Data for 2013-14

Company	Underground	Opencast	Total (MT)
ECL	6.87	29.18	36.05
BCCL	2.7	29.91	32.61
CCL	0.95	49.07	50.02
NCL	0	68.64	68.64
WCL	7.73	32	39.73
SECL	16.42	107.85	124.27
MCL	1.43	109.01	110.44
NEC	0.003	0.66	0.66
Total - CIL	**36.11**	**426.31**	**462.42**
SCCL	**10.36**	**40.11**	**50.47**

However, use of long wall technology, wherever, geo-mining conditions permit, will be continued as a mass production technology. There will be a judicious mix of B&P with continuous miner, B&P with Side Discharge Loader (SDL)/Load Haul Dumper (LHD), combination of mechanized longwall and special mining methods.

Many underground mines are having long travelling distances about 3 to 5 km. or more which take away considerable amount of time spent on to and fro journeys to the working places. Making provision of underground Man riding system, which will be cost effective too, can considerably reduce this precious time loss on travelling.

Most of the underground mines in ECL & BCCL are in losses. Steps are being taken by CIL to make loss making mines profitable.

The major reasons for loss in these mines:

a. Non-productive manpower.
b. Age old / obsolete machines.
c. Geo-mining / Geo-technical problems in the mines.
d. Mines having age old problem of high spontaneous heating, presence of water logged workings etc.
e. Unscientific / unplanned mining prior to Nationalization.
f. Poor utilisation of machines
g. Industrial relation problem mostly in uneconomic mines.
h. De-watering cost is very high in some of the mines.

The major steps required to revive loss making mines into profitable entities are:

a. Phasing out of manual system of loading to mechanize system mainly by **introduction of Side Discharge Loader (SDL) / Load Haul Dumper (LHD)**
b. Wherever geo-mining condition permits, mass production technology is introduced.
c. Rationalization of manpower.
d. Efficiency improvement in underground and opencast mines.
e. Re-organization of UG Transport System.
f. Improvement of equipment utilization.
g. Re-organization of mines.
h. Sorting out of problems through negotiation, thus reducing 'Man Days' loss.

3. IMPROVEMENT OF EQUIPMENT UTILIZATION

The production performance of mining equipment depends on its availability and utilization. Hence it is necessary to determine the percentage availability and utilization of machinery with an aim to improve the same. Different mines are following different terms and maintaining different information. The only common information in most of the mines is the working hours of SDL's. There is a need to develop proper feedback and to define terms, factors and indices relating to mining equipment. These would serve as management's tool in improving performance. These can also be used for inter-firm comparisons. To sum up, there is a necessity to lay down on systematic basic, well defined terms, factors and indices required for control and management of mining equipment. For assessment and analysis of the performance of equipment one must keep proper and up- to-date records regarding the following operational parameters. [3]

3.1. Total Shift Hours (TSH)

This means the total number of hours during the period of observation. It is equal to 26*24*3=1872 hours in a quarter. This can be further divided into Total Shift Hours,

Scheduled Shift Hours, Machine Available Hours and Machine Working Hours in a shift. Machine available hours are further breakup into machine worked hours and machine idle hours.

3.2. Scheduled Shift Hours (SSH)

This means number of hours, the mine employing the machinery is supposed to work in a year. This is a management's decision after giving due consideration to the production target, geo-mining conditions, the technical parameters, capital investment involved, market conditions, labour conditions etc. The higher the capital investment, the higher should be the figure for scheduled- shift – hours. In advanced countries equipment work very long shift hours round the clock.

In India, the general tendency is to work effectively for 18 hours a day and six days a week. The mines under consideration, the equipment are planned to work for three shifts of eight hours each. Two hours per shift are for travel time and preparation time. So the scheduled shift hours are 18 hours per day.

3.3. Machine Available Hours (MAH)

This means the number of hours, out of schedule shift hours; a machine is available for work at a face. The maintenance program dictates it. Technical department's expertise and availability of spares have bearings on this. This also indicates how earnest and agile the management is to get maintenance and spare supply departments.

3.4. Machine Worked Hours (MWH)

This information is very important as it reflects the efficiency of coordination of various operations of production departments. Lack of coordination may result in machine being idle for want of blasted coal or matching equipment etc. Difference between machine available hours and actual hours of use measures the lapse of operating department. Machine worked hours include idle hours which are due to various delays.

4. INFLUENCING FACTORS AND INDICES

From the basic information collected, as above availability and utilization factors both on schedule-shit-hours basis and on machine-available – hours basis, production efficiency and overall efficiency can be determined. In the following paragraphs these factors and indices have been defined and their importance exaggerated.

4.1. Percentage Availability (PA)

A machine is considered available when it is fit to be put to perform its work, that is in working condition. The availability is determined by dividing the hours the machine is available and is used plus the hours it is available but not used due to various reasons over a period of time. It is normally expressed in percentages. Number of scheduled-shift-hours in a period of time for equipment operation is taken as total shift hours. Overtime hours of work if any are added to the total shift hours. Stoppage of less than 15 minutes is ignored and the machine is taken as having been used during that period.

Percentage availability helps in judging and comparing the efficiency of the maintenance departments of different units. This can also assist the management in knowing how the availability of machine would change by changing the scheduled shift hours of work. Percentage availability of machine would change by changing the scheduled shift hours of work.

$$PA_{TSH} = \frac{\text{Machine Available Hours}}{\text{TSH}}$$

$$PA_{SSH} = \frac{\text{Machine Available Hours}}{\text{SSH}}$$

4.2. Percentage Utilization (PU)

This is defined as the ratio of the time in hours the machine is actually used in duration to the total hours. Here the denominator, i.e. Total Shift hours can be either total duration of Scheduled–Shift–Hours (SSH) or total Machine Available Hours (MAH) in duration and depending upon that the value of PU will change. As MAH is always less than SSH, PU, based on MAH will be higher than PU based on SSH. Similarly MWH is also always less than MAH and SSH, thus PU based on MWH is definitely higher than PU based on MAH and SSH.

$$PU_{TSH} = \frac{\text{Machine Working Hours}}{\text{TSH}}$$

$$PU_{SSH} = \frac{\text{Machine Working Hours}}{\text{SSH}}$$

$$PU_{MAH} = \frac{\text{Machine Working Hours}}{\text{MAH}}$$

PU_{TSH} is a measure of the planning and efficiency of management
PU_{SSH} reflected both maintenance and supervisory staff efficiency, whereas value of
PU_{MAH} indicated the enthusiasm and effectiveness of operational staff alone.

4.3. Production Efficiency (Pe)

$$\text{Production (Pe)} = \frac{\text{Actual Output}}{\text{Production efficiency Target output}} \times 100$$

Figure of output may be for an hour or shift or a year. As a matter of fact it is the product of equipment operating efficiency and the job management efficiency. Here it is necessary to mention something about equipment operating efficiency and the job management efficiency. Equipment operating efficiency is determined by the capacity at which it is operating as compared to its rated capacity. Influencing factors are within the equipment-sluggish behavior of various systems and sub-systems, etc. Job management efficiency is influenced by external and environment factors, - working environment, human skill, etc. their values are only empirical ones. Table 2, 3 and 4 give values of them applicable in most of mining conditions.

Table 2 - Equipment operating efficiency

Equipment operating efficiency	Remark
0.90	Excellent
0.80	Good
0.70	Average
0.60	Fair
0.50	Poor

Table 3 - Job management efficiency

Job management efficiency	Remark
1.00	Excellent
0.90	Good
0.80	Average
0.70	Fair
0.60	Poor

Table 4 – Combined Efficiency Factor (Production Efficiency)

Combined Efficiency Factor	Remark
0.95	Excellent
0.85	Good
0.75	Average
0.65	Fair
0.55	Poor

When the SDL is operating as an independent unit such as empty travel-spotting-loading-loaded travel-spotting-unloading, the production efficiency is equal to equipment efficiency. But when the SDL is part of a coal production system both equipment operating efficiency and job management efficiency are obviously to be considered.

4.4. Overall Efficiency (Oe)

It is the product of Utilization Factor on the basis of Scheduled Shift Hours and Production Efficiency

$$\text{Or, } Oe = Pe \times PU_{MAH}$$

It is an overall performance measure and is the one in which the top management is actually interested. A Manipulation in Utilization factor by recording more operation time or in production efficiency by recording less time cannot alter or inflate the figure in Overall Efficiency.

5. ANALYSIS OF AVAILABILITY AND UTILIZATION OF SDL

The details regarding working hours, repair hours, idle hours, of SDL from various mines for a period of three months have been collected and analyzed. The values for the period are given in Table 5.

Table-5 Availability and Utilization of SDL

Parameters	Machine/Mine				
	SDL-1/01	SDL-1/02	SDL-1/03	SDL-1/04	SDL-1/05
Total Shift Hours (TSH)	1872	1872	1872	1872	1872
Scheduled Shift Hours (SSH)	1404	1404	1404	1404	1404
Machine Maintenance Hours (MMH)	213	224	198	183	230
Machine Breakdown Hours (MBH)	113	96	148	151	89
Machine Repair Hours (MRH)	102	90	131	129	139
Machine Available Hours (MAH)	1078	1084	1058	1070	1088
Machine Worked Hours (MWH)	849	908	809	781	946
Machine Idle Hours (MIH)	229	176	249	289	139
% Availability of TSH	57.58	57.90	56.51	57.15	57.95
% Availability of SSH	76.78	72.20	75.35	76.21	77.27
% Utilization of TSH	45.35	48.50	43.21	41.72	50.53
% Utilization of SSH	60.47	64.67	57.62	55.62	67.37
% Utilization of MAH	78.75	83.76	76.46	72.99	87.18
Target Production in Tonne	9750	9750	9750	9750	9750
Actual Production in Tonne	7530	7992	7251	6885	8737
Machine Productivity in Tonne	96.53	102.46	92.96	88.26	112.01
Production Efficiency	77.23	81.96	74.36	70.61	89.61
Overall Efficiency	68.85	73.31	66.12	63.11	78.49

The percentage availability and utilization on TSH, SSH and MAH basis for SDL, have been shown in Fig 2, and Fig 3 respectively.

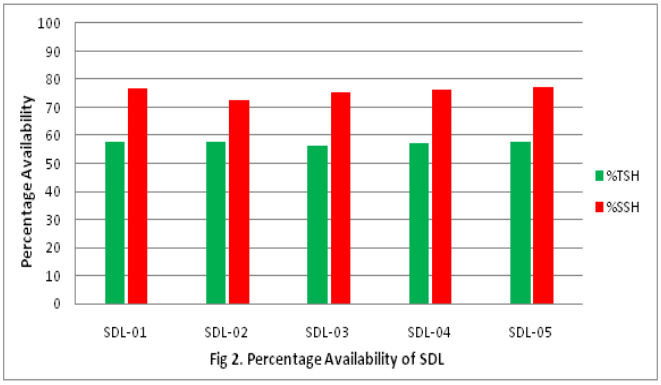


Fig 2. Percentage Availability of SDL

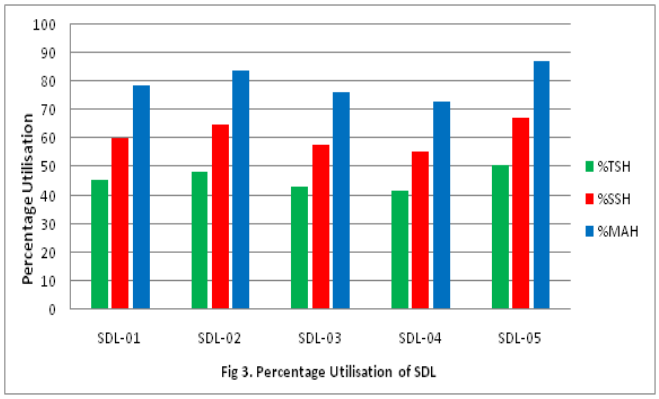


Fig 3. Percentage Utilisation of SDL

Fig 4, Fig 5 and Fig 6, shows the SDL machine production capacity, machine productivity and machine overall efficiency.

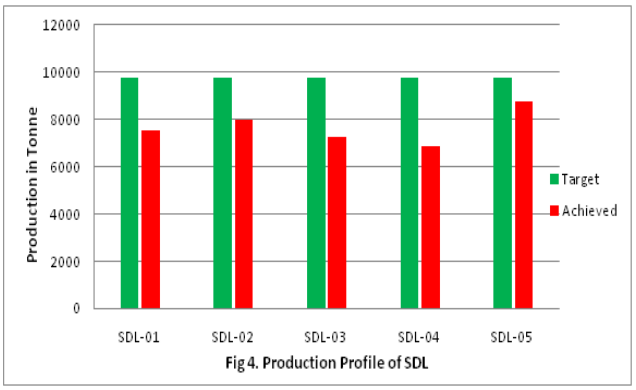


Fig 4. Production Profile of SDL

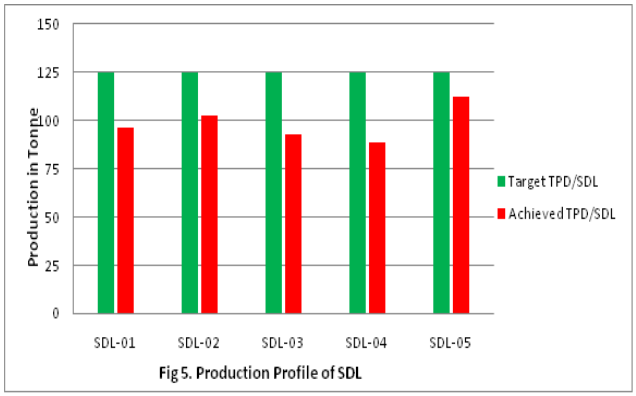


Fig 5. Production Profile of SDL

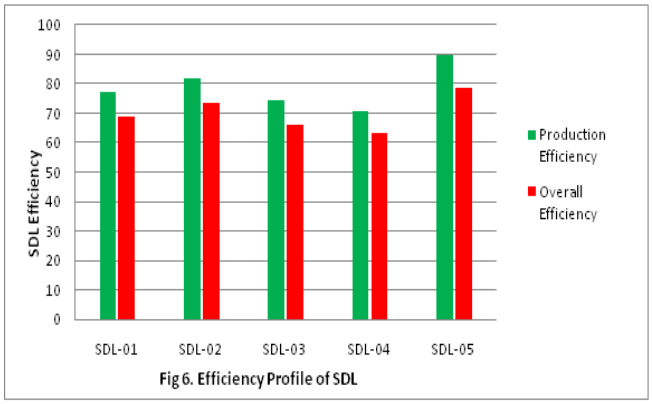


Fig 6. Efficiency Profile of SDL

The values of percentage availability and utilization of SDL's are given in Table-6.

The CIL Standards (C.M.P.D.I norms for Coal India Limited) for those values have been given within brackets for comparison purposes. Values with brackets indicate C.I.L.norms.

Table 6 Comparison of percentage availability and utilization with C.I.L standards

Equipment	Availability on SSH basis	Utilization on SSH Basis
SDL-1/01	76.78 (80)	60.47 (70)
SDL-1/02	72.20 (80)	64.67 (70)
SDL-1/03	75.35 (80)	57.62 (70)
SDL-1/04	76.21 (80)	55.62 (70)
SDL-1/05	77.27 (80)	67.37 (70)

Table 7 gives the percentage of unscheduled hours, unavailable hours, unutilized hours, utilized hours and average value with respect to total shift hours.

Table 7. Percentage Distributions of total shift hours for three months

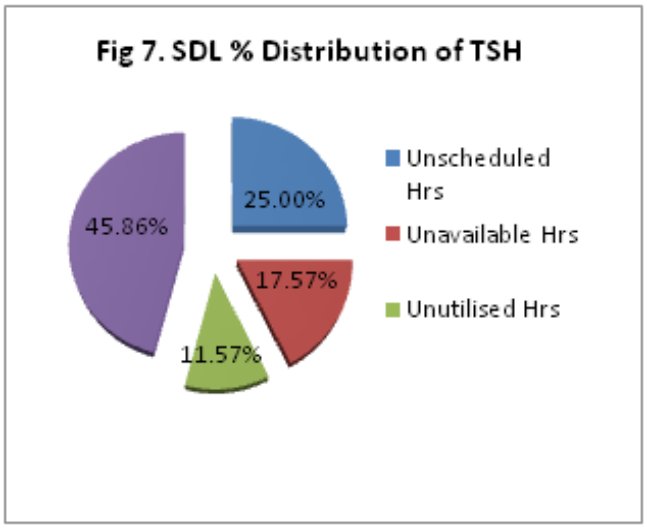
Parameters	Machine/Mine					
	SDL-1/01	SDL-1/02	SDL-1/03	SDL-1/04	SDL-1/05	Average
Unscheduled hours	25.00	25.00	25.00	25.00	25.00	25.00
Unavailable hours	17.41	17.09	18.48	17.84	17.04	17.57
Unutilized hours	12.24	9.41	13.31	15.44	7.43	11.57
Utilized hours	45.35	48.50	43.21	41.72	50.53	45.86
Total	100.00	100.00	100.00	100.00	100.00	100.00

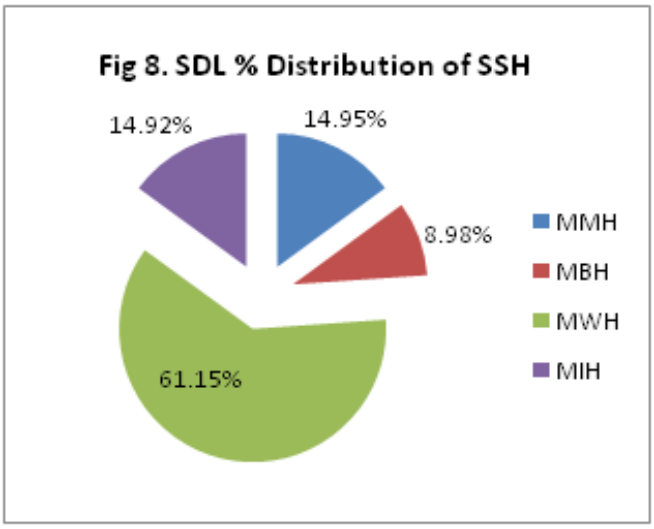
Table 8 gives the percentage of Machine Maintenance Hours, Machine Breakdown Hours, Machine Worked Hours, Machine Idle Hours and average value with respect to scheduled shift hours.

Table 8. Percentage Distributions of scheduled shift hours for three months

Parameters	Machine/Mine					
	SDL-1/01	SDL-1/02	SDL-1/03	SDL-1/04	SDL-1/05	Average
Machine Maintenance Hours (MMH)	15.17	15.95	14.10	13.03	16.38	14.92
Machine Breakdown Hours (MBH)	8.04	6.83	10.54	10.75	6.33	8.98
Machine Worked Hours (MWH)	60.47	64.67	57.62	55.62	67.37	61.15
Machine Idle Hours (MIH)	16.32	12.55	17.74	20.60	9.92	14.95
Total	100.00	100.00	100.00	100.00	100.00	100.00

Fig 7 and Fig 8, shows the percentage distribution of total shift hours and scheduled shift hours for the period.





6. DISCUSSION OF ANALYSIS

The results of the analysis show that the unscheduled hours are very high since the equipment are scheduled only for six hours in a shifts, that also include maintenance hours in scheduled shift hours. The availability of the equipment is very low compared to total shift hours where as availability of the equipment on SSH basis is comparable with that of CIL standards, but there is a wide gap between availability and utilization of equipment. The percentage utilization of machinery is far below normal. The productivity of SDL is not upto the mark. Hence the management has to take steps to improve the equipment utilization. There is improper maintenance planning as reflected in the studies which affects availability of machine by frequent breakdowns. It can be also noted that there is lag between machine repair hours and machine breakdown hours which indicate how efficiently the management is attending the faults. Machine unutilized hours is a major factor for low utilization when sum up with unscheduled hours which shows the job management efficiency. The production efficiency of machines is noticeable and satisfactory but overall efficiency is poor which suggests there is lack of team work.

7. SUGGESTIONS

The productivity of an underground coal mine is affected by several factors. There is always scope for improvement regarding productivity and overall effective use of resources. This paper throws lights on the parameters affecting the machine efficiency, productivity of mines and manpower management. The following measures required to be adopted to enhance SDL performance.

1. Effective working hours to be increased in a shift to increase machine available hours and working hours. From the analysis, if overlapping shift operation is adopted, then availability increases by 25%, from present 57.32% to 82.32%. Likewise machine utilization can be increase to 72.43%.
2. Timely start of the face operation, if necessary the shift timings of the machine crew and coal preparation crew may be staggered to minimize machine idle hours.
3. Scheduled maintenance of machine and adequate provisions of trained manpower should be ensured to minimize machine breakdown.
4. Where travel distance is excessive, introduction of suitable man-riding system based on techno-economics should be explored.
5. Compatibility and up-keep of out-by transport system is vital to achieve production norms.
6. Evaluation of geo-mining conditions before introduction of these machines especially seam height in case of tub loading and nature of floor strata is must.
7. Better organization of manpower and its management to infuse team effort.

8. CONCLUSION

Availability and utilization study is a known method to measure performance of production equipment in manufacturing industries and adapted for mining industry in this paper. From the above studies various steps can be taken to improve availability and utilization of SDL machine so that its performance is better and productivity is more. Given the above measures if practiced, Bord and Pillar mining is certain to keep its "tryst with destiny" by playing its role towards meeting the energy requirement of the nation. The views expressed in this paper are solely of the author and not necessarily of the organizations, where the studies are undertaken.

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REFERENCES

[1]. Devi Prasad Mishra, Mamtesh Sugla, Prasun Singha (2013): Productivity improvement in underground coal mines – a case study, J. Sust. Min. Vol. 12 (2013), No. 3, pp. 48–53

[2]. Reliability modelling and performance analyses of an LHD system in mining by B. Samanta, B. Sarkar, and S.K. Mukherjee (2004): The Journal of The South African Institute of Mining and Metallurgy, January/February 2004

[3]. M.E. Michael Arputharaj (2015): Studies on availability and utilization of mining equipment-an overview, IJARET, Volume 6, Issue-3, march-2015, pp. 14-21.

[4]. New Technology and Challenges for Underground Coal Mining.[online] www.ibkmedia.com/userfiles/.../event_8-8-3-50058b712259a.doc (May, 2013)

[5]. Kulshreshtha M., Parikh J.K. (2001): A study of productivity in the Indian coal sector. Energy Policy 29(9), pp. 701–713.

[6]. Sharma S.N., and Surana D.M., (1972): Analysis for Performance Assessment and Performance Control of Dipper Shovels used in Mines: Journal of Mines, Metals & Fuels, August,1972.

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