

Operational Analysis of Mining Equipment in Opencast Mine using Overall Equipment Effectiveness (OEE)

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Abstract:- Man and Mining equipment work in highly polluted environment, where every individual undergoes various stresses for improving equipment effectiveness and productivity of the mine. Mining equipment especially Shovel has undergone complex changes in terms of automation using sensors where the effective utilization of the equipment is still below the benchmark values. Mining companies are finding it hard to survive due to high maintenance and production cost. Performance of the mining equipment is highly affected by unnoticed minor stoppages and idle equipment, in such cases it becomes significant to measure the performance of man and machines by an effective tool known as Overall Equipment Effectiveness (OEE) for improving the Performance of the machines and Productivity of the mine.

Keywords:- TPM, Availability, Performance, Utilization, Overall Equipment effectiveness (OEE).

I. INTRODUCTION

Mining involves very costly and highly automated equipment for extraction of minerals, the size of the equipment and capacity has increased many folds in the recent past resulting in poor utilization and inefficiency of the machines. Mining managers are focused on effective utilization of the equipment so as to get early returns on their investments [4]. Maintenance of the equipment in the past has been a neglected area and the management did not give it the due importance. It has been observed that the cost of maintenance for surface mining Equipment varies from 30-50% of the total operational cost in mechanized mine [7]. The overall culture in the organization needs to be addressed by changing the mindset of the employees that I operate you maintain it [8]. It was observed by the Japanese that automation (hardware and software) alone cannot give optimum results but is more dependent upon the operators of that technology. They should jointly determine the best method to operate and maintain the equipment and upkeep of the equipment [3]. It is now essential to reduce the unplanned down time by making use of the preventive maintenance. If the maintenance is not carried up to the adequate level, the mining machines can result into lower speed of operation, premature failure, and reduced capacity or even can demand replacement of the costly equipment. It is not advisable to keep the standby equipment due to high procurement cost. A case study has been carried out for Northern Coal fields one of the mega mine of Coal India Limited. Since most of the Heavy Earth Moving Machinery (HEMM), being used in developing countries is obsolete due to over aging of the equipment and cannot be replaced on account of high cost of replacement, but is still being used. These mining equipment are needed to be replaced to reduce the production losses as these equipment's stay mostly in the Breakdown conditions.

II. TOTAL PRODUCTIVE MAINTENANCE (TPM)

Maintenance term is confusing in mining concept, if it is not related to involvement of the machine operators and the maintenance employees at all level for reducing downtime, increase performance of machines for better equipment effectiveness and productivity of the mine.

2.1 Role of Total Productive Maintenance in reducing Downtime.

The concept of TPM was given by Nakajima in the year 1971 in Japan, which states that it is the joint responsibility of the operators and the maintenance staff to upkeep the machines [9]. The operator of the machinery needs to be trained to perform many small issues of maintenance and fault finding [5]. Small teams of production and maintenance staff should be formed for reducing the downtime for effective utilization of the equipment and hence increase the life cycle of equipment. The main objective of the TPM is to reduce the breakdowns to zero, zero defects in operation and maintenance so that there are almost zero wastage and zero accidents [3].

2.2 TPM and OEE.

In today’s era of stiff competition, any organization can only be highly productive, if there is high operational efficiency and effectiveness [2]. The objective of TPM is to strive for three Goals in terms of Zero defects, Zero accidents and Zero breakdown to improve the Quality cost, cost of Product and productivity of the system. TPM holds the concept of continuous improvement in the system by participation of all members from different departments [5]. TPM concept is therefore helpful for maintaining work culture and sense of ownership, where the concern of an organization is more important than their own family.

The effectiveness of any Production equipment can be measured by important tool called as Overall Equipment Effectiveness (OEE). OEE is mainly a TPM metric. Most of the equipment that is used for Mining production are either excavators for cutting and Dumpers for transporting the minerals. It is therefore required to replace the quality rate with the utilization rate [1]

III. MAJOR LOSS EVENTS AND AFFECTED OEE METRIC

OEE of the mining shovel needs to be improved by reducing the down time losses, speed losses and the utilization losses. These losses severely affect the OEE metrics like Availability, Performance and Utilization [10]. Detail discussion is being carried out in the Table 1 below to specify the factors responsible for affecting the OEE.

Table 1

Loss Category	Affected OEE Metric	Factors for Loss Category
Down Time Losses	Availability	-Equipment failure. -Unplanned Maintenance. -Machine warm Up. -Material Shortage. -Machine Changeovers.
Speed Losses	Performance	-Over aging of Equipment. -Operator Training Level. -Part jamming. -Idling and Minor stoppages. -Job Conditions like snow, dust, fog etc. -Operator Inefficiency.
Utilization Losses	Utilization	-Equipment Standby. -Assembled Incorrectly. -Rework.

IV. OEE FOR MINING

The original definition for OEE made use of Availability, Performance and Quality factor. Since it is difficult to note the Processed and Defect amount for calculation of Quality factor, therefore OEE for mining applications make use of utilization factor instead of quality factor [1][5].

Therefore the OEE of mining shovel can be measured by Calculating the Availability (A), Performance efficiency (P) and Utilization (U) as per equation (1).

$$\text{Overall Equipment Effectiveness (OEE)} = \text{Availability} * \text{Performance Rate} * \text{Utilization.} \quad (1)$$

Availability

The operational Availability (A) of the equipment is dependent on the equipment downtime (comprising of maintenance, breakdown Hours and Idle Time).

$$A = \frac{(TH-DT-IT)}{TH} * 100$$

Where TH is Total Hours, DT is Down Time Hours and IT is idle time.

Performance

The performance of the equipment is dependent on propel time, Idling and Minor stoppages due to Job Conditions such as dusty, snow, fog and speed loss due to reduced speed of working on account of aging of the Equipment and operator inefficiency.

$$P = \frac{\text{Net production time}}{\text{Actual available time}}$$

Utilization

Utilization of an Equipment is affected by the Down time and standby Hours due to wrong reassembly and rework.

$$U = \frac{[TH-DT-IT]}{TH-DT} * 100$$

V. PRODUCTION

Weekly production of the Mining shovel is directly affected by the OEE of the equipment, can be calculated by equation as below [4].

$$P = \text{Shift Hours} * 60 * \text{Bucket Capacity} * \text{OEE} * \text{Buckets per minute.}$$

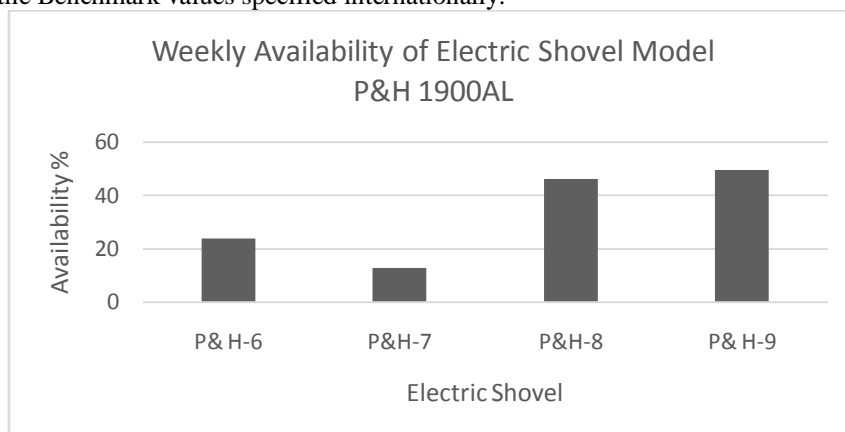
Bucket Capacity for P&H 1900AL Electric shovel is 10 Cubic meter and Buckets produced per minute ideally as per time study is 2.857. OEE and weekly production of the Electric shovel for one of the mega mines of Coal India limited has been carried out tofor case study to examine the effectiveness of the equipment as shown in Table 2.

Table 2

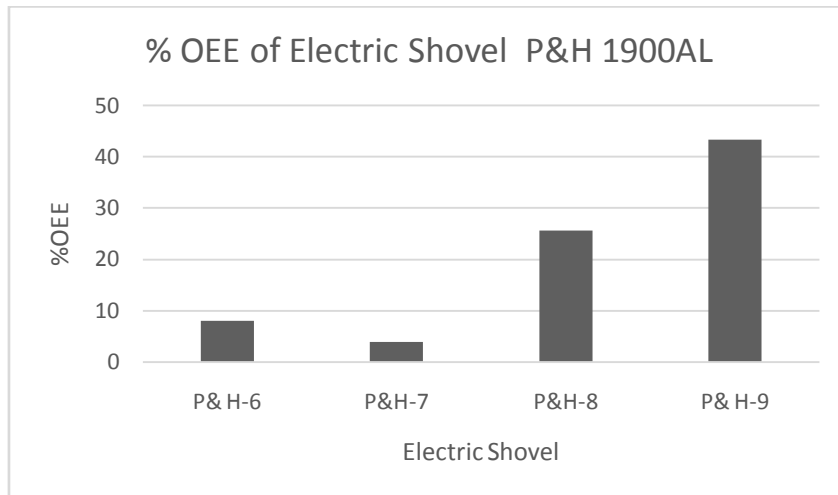
Equipment Model	Shift Hours	Working Hours	Maintenance Hours	Breakdown Hours	Idle Hours	Average Speed Loss Hours per week	Average Propel Loss Hours per week	% Availability.	% Performanc.	% Utilization.	% OEE	weekly Production (P) m ³
Electric Shovel P&H 1900AL												
P&H-6	144	33.3	6.09	64.58	39.23	6	3	23.7	36.1	46	3.92	9676.32
P&H-7	144	18.07	105.35	7.14	13.04	6	3	12.8	51.27	58.1	3.81	9404.78
P&H-8	144	65.46	4.46	37.15	36.13	6	3	46	86.4	64.5	25.5	62945.42
P&H-9	144	71.02	3.27	69.31	0	6	3	49.6	87.39	100	43.3	106957.85

VI. CASE STUDY

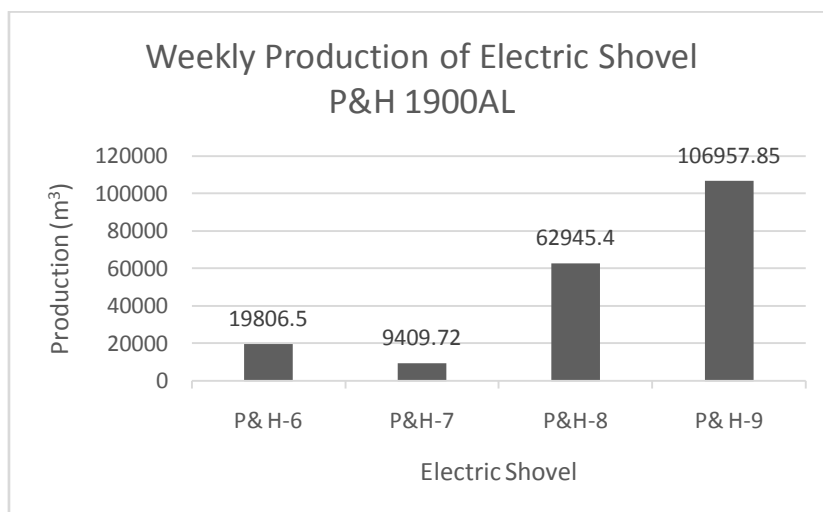
Mining shovel which is the most important equipment for excavation and loading of ore, play a significant role in productivity of mine. Weekly data for case study for the month of June'2014 has been taken from field survey from Northern coal fields one of the mega mine of Coal India Limited to study the effectiveness of the Mining equipment considering the last day of the week as holiday. Graphical analysis for the electric shovel model 1900AL has been carried out. Availability of the shovel shows none of the shovels are able to achieve the Benchmark values specified internationally.



Shovel P&H-6 and P&H-7 has availability of less than 25% which is much below the Benchmark value of 90%, the main cause is more breakdown hours and more time taken by maintenance staff for repair. Availability of equipment around 50% is considered an acceptable level taking into considerations the environmental conditions.



Shovel P&H-6, P&H-7 and P&H-8 have overall equipment effectiveness of less than 30% due to poor availability, performance and utilization of these two equipment's. The idle time Hours spent are needed to be reduced.



Weekly production of the shovel has been calculated & it is known that the production level of the Electric Shovel P&H-6, P&H-7 and P&H-8 is much below the weekly Productivity of Shovel P&H-9, which is very serious issue.

VII. CONCLUSION

1. Utilization is most important factor for OEE calculation as compared to availability and Performance, as this factor considers not only down time due to breakdown but also considers the standby time, therefore this Utilization factor needs to be improved for improving OEE and productivity of mining shovel.
2. Productivity from the shovels can be improved by reducing the idle time, Poor OEE and Lower production in case of mining shovel P&H-7 indicates the ineffectiveness of the equipment and maintenance staff took more time to repair. This shows the maintenance staff need to be trained on regular basis. If the equipment is in the breakdown state due to aging most of the time, then efforts should be made to replace the equipment.
3. Performance factor shows the equipment is not operated to the specified maximum speed and hence causing poor productivity of the mine. Reasons for poor performance shows the operator inefficiency due to aging of the equipment and operators attitude to use the equipment at less than the prescribed speed. In such cases the operators should be motivated and should be given the sense of ownership.
4. Since OEE is an Improvement measure, OEE calculations help in making improvements in productivity by gradual improvement of availability, Performance and utilization over the months and year. The bench mark values specified indicates that any production company should take care that the breakdown hours are

less and the maintenance staff should bring the equipment in the working state at the earliest so as to improve the availability, performance and utilization of the production equipment, any efforts made to reduce these losses can gradually help to improve the productivity of the system.

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