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Weight based determination of influencing factors responsive to continuous mining system in India

India is one of the most important coal producing countries globally; majorly produces through opencast mining. However, environmental limitations and fast depletion of near the crust reserves is forcing to replace the opencast coal mining activity with effective underground mass coal production technology. One of such technology compatible with Indian mining scenario is continuous miner (CM) technology. India has already adopted this technology by implementing few of these machines to some of the underground mines, but the performance of majority of these machines are the matter of concern as they are not effective in terms of return on investment. This has exposed a broad arena of research for the improvement of productivity and finally of economy. This paper actually depicts the machine availability trend of a CM deployed in a mine belonging to one of the largest coal producing public company of the country. The availability of the overall system and sub-systems were analyzed, a discussion was made with experienced mine personnel to obtain miner's perspective towards the lower availability of the system and sub-system. Finally appropriate recommendations were suggested to overcome the lower availability trend of the system and sub-systems. Implementation of these remedial measures may not only improve the availability trend of the machine but also form a firm basis of development of a proper preventive maintenance programme for all such machines focusing on betterment of their performance in Indian scenario.

Keywords: *Continuous miner, geo-mining condition, sub-system, availability.*

1. Introduction

Coal is one of the major mineral for various industries, including most of the powerhouses throughout the globe. Continuous miner (CM) machines are proven as an effective technology for underground coal production and in line with this; India has also introduced these machines to some of the selective underground mining projects since nearly a decade. The effectiveness of these machines deployed in Indian mining scenario is not alike the global standards. This may be due to variation in geo-mining condition or continuation of working in formerly as well as partially exploited panels with room and pillar technique for coal production.

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India is one of the major players in coal production sector; specifically it ranks third in global coal mining sector; in the year 2018 India produced 715.13 mt. of coal as per the report of Ministry of Coal, Government of India [1]. However, a report published in 2018 by Indian Bureau of Mines indicates that almost 93% of overall coal production in India is through opencast mining technique [2], rest is through underground mining method. The contribution of underground mining is much larger for other coal producing nations, which can be seen from the following graphical representation depicted in Fig.1. Relevant data is obtained from online available resources of Geo-Science, Australia of Australian Government [3], U.S. Energy information administration [4], Department: Energy; Republic of South Africa [5] and the statistics of China is obtained from an article C. Chu, R. Jain, N. Muradian, and G. Zhang (2016) [6].

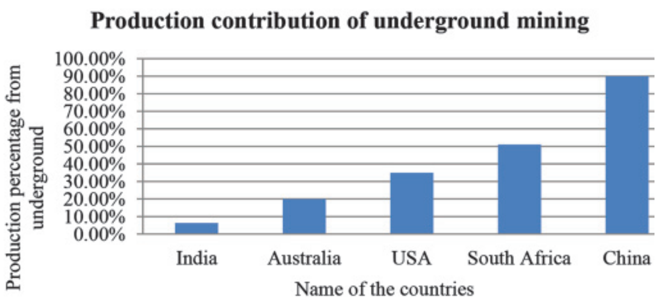


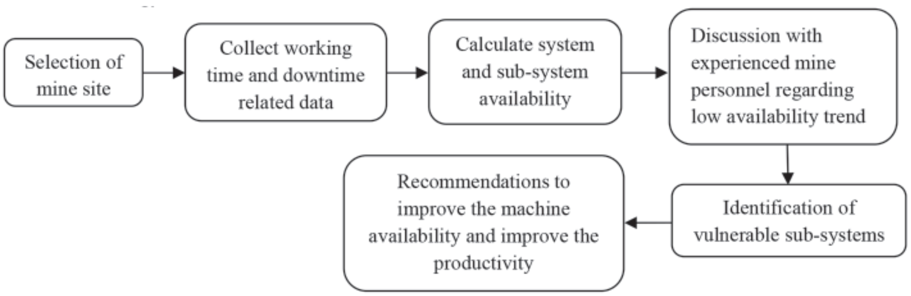
Fig.1: Percentage contribution of underground mining among overall production for different coal producing nations.

Now, the global environmental concerns and depletion of near the crust reserve is forcing the government to think of some alternatives (Ghosh, 2007) [7]. The only viable alternative available to exploit the deeper seams with relatively less pollution is underground coal mining. Underground mining technique has lesser direct environmental interference, thus causing considerably less pollution as compared to opencast mining method (Sahu, Parakas and Jayanthu, 2015) [8].

Utilization of coal in diverse industrial sectors of India demands constant and continuous production of coal. Underground mass production techniques such as: longwall technique and CM technology are considered important to be implemented to meet the demand (Banerjee, 2019) [9]. Therefore, implementation of cutting edge underground mining technology is important from higher productivity point of view.

This paper depicts the condition of an underground coal mine in India working with one CM machine; deployed for depillaring of the panel. The trend of sub-system availability and overall machine availability is depicted. A glimpse of discussion with experienced mine personnel is also presented, which may be useful for development of a proper preventive maintenance programme and for improvement of overall performance, availability as well as productivity.

2.0 Methodology



Mine site is situated in the south-central part of the country; where a CM is deployed to produce underground coal. The working time and downtime related data for a period of four months was recorded; which was used to calculate the system and sub-system availability. Based on the results obtained from the availability analysis, a discussion with experienced mine personnel is accomplished. The analysis and discussion jointly helped in identification of the vulnerable sub-systems. Based on this overall analysis and discussions few recommendations to improve the lower availability trend and productivity are suggested.

Availability of a machine is defined as the percentage of time a machine is actually available to perform its desired task among the total stipulated time for production in a defined environment.

Overall system availability is directly affecting the production time and is the reflection of sub-system availability.

2.1. Few essential parameters to calculate availability:

2.1.1 Scheduled working time

Total time duration for which production has been planned.

2.1.2 Scheduled maintenance time

Time provided within each cycle of production run for routine maintenance.

2.1.3 Downtime

Time during which a machine is stopped unintentionally, due to some breakdown or interruption of allied systems or unavailability of spares or raw material

2.1.4 Actual available time for production

This is the time that remains after subtracting scheduled maintenance time and other downtimes from scheduled working time. This is the time for which a system actually operates to perform its desired task.

Actual available time = Scheduled working time- (Scheduled maintenance time + Downtime)

$$\text{Availability} = \frac{\text{Actual available time}}{\text{(Scheduled working time – scheduled maintenance time)}}$$

3.0 Mine description

The mine site under study belongs to one of the major coal producing public company of the country. The mine site is pretty old and developed nearly up to its limits. The CM machine was deployed since few years for the development of the panel and currently engaged in depillaring purpose. The geo-mining condition of this mine site is depicted in the Table 1.

The immediate roof of the panel is sandstone and having a RMR of 62; which is a pretty good value and considered as a safer panel to workout with.

The seam thickness is 6.5 meter; which is considerably thick and is not completely compatible to workout with CM; as the thickness of seam is considerably more as compared to maximum reach of 3.6m for continuous miner, therefore large amount of coal is left unattended and causing a considerable production loss. This left out coal can be produced either through induced blasting or by replacing CM technology with effective thick seam mining techniques.

4.0 Description of systems and sub-systems of a CM machine

A continuous miner (CM) is a machine dedicated for underground coal production. For the ease of this study the overall CM based system is divided in a few of the following sub-systems:

4.1. Electrical: It includes all the electrical components such as motors, cables and all other components integrated as power distribution systems.

TABLE 1: GEO-MINING CONDITION OF THE MINE SITE UNDER STUDY

Gallery width	Depth of cover	Height of working	Pillar size	Gradient	Seam thickness
6.5m	200-315 m	4.6m	45m × 45m	1 in 7.5	6.5m

4.2. Hydraulic: It includes all hydraulic systems such as pumps, ram and cylinder arrangements such as lifting mechanism of the cutting boom etc.

4.3. Cutter: It is the cutting mechanism mounted at the end of the cutting boom to shear the coal layers from the face.

4.4. Traction: This includes the mechanism integrated to move the CM machine. Basically the traction system of the CM machine is a crawler chain based system.

4.5. Chassis: It is the main structure of the machine, which bears the major load of all integral components.

4.6. Gathering: It is the arrangement provided beneath the cutter on the apron to collect the coal as the CM machine moves forward.

4.7. CM conveyor: This is the elevation adjustable chain conveyor provided with the purpose of loading coal to the shuttle car.

4.8. Feeder breaker: It is the crushing unit which comes with the overall CM package. After shearing of the coal face, produced lumps are required to be crushed to smaller size before further processing; this is performed by feeder breaker.

4.9. Outbye conveyor: These are the main conveyors of the mine, dedicated for transportation of coal from the feeder breaker to the surface.

4.10. Shuttle car: It is used to convey coal from the CM machine to the feeder breaker. Some manufacturers' combine their machines with a pair of electrically operated shuttle car and others provide diesel operated ram car within the overall CM package. In this site under study electrically operated shuttle cars were deployed.

5.0 Discussion with experienced mine personnel

A discussion with experienced mine personnel was carried out after the mine visit, to identify the people's perspective of low productivity trend and the probable ways to deal with it. Here, the glimpses of the outcomes of that discussion are presented in a nutshell:

5.1. Mucky floor condition obstructs the free maneuverability of the machine and results in frequent damage to the traction system.

5.2. Improper inspection and maintenance of the motor sealing to resist access of water.

5.3. Improper inspection of the belt and allied components of the conveyor system.

5.4. Electrical breakdowns, such as cable faults and other electrical transmission damages are common from the non-availability point of view.

5.5. Cutting drum and pick damage are among few of the common mechanical breakdowns causing unavailability.

5.6. Improper maintenance of the route for the movement of the shuttle cars makes the system more prone towards failure.

Above mentioned points are based on the discussions on questionnaire made for the purpose with twenty miners working in the corresponding mine. The percentage weightage of most vulnerable system or causes for lower availability trend as per the miner's perspectives are given in the following Table 2.

TABLE 2: PERCENTAGE WEIGHTAGE OF SELECTING ANY SPECIFIC REASON OF LOW PRODUCTIVITY BY SELECTED EMPLOYEES

	Vulnerable reasons towards low availability as well as productivity	Percentage of selecting any specific reason by selected employees
1	Mucky floor condition and problem in maneuverability of CM and shuttle car	50%
2	Electrical breakdowns (cable and other transmission faults)	20%
3	Outbye conveyor breakdown	15%
4	Cutter and pick related breakdowns	10%
5	Hydraulic breakdowns and improper sealing of motors	5%

TABLE 3: AVERAGE SYSTEM AVAILABILITY DURING THREE MONTHS UNDER STUDY

	Month	Average system availability
1.	First month	0.6099
2.	Second month	0.5783
3.	Third month	0.5759
4.	Fourth month	0.6028

6.0 Results and observations

The availability trend of the continuous miner machine during the four months of study is depicted in the Table 3. The availability analyses (day wise) of CM machine as well as subsystem availability analysis are further depicted through figures as follows.

The availability trends of the system for each month within the period of four months under study are depicted graphically through the Figs.2 to 5.

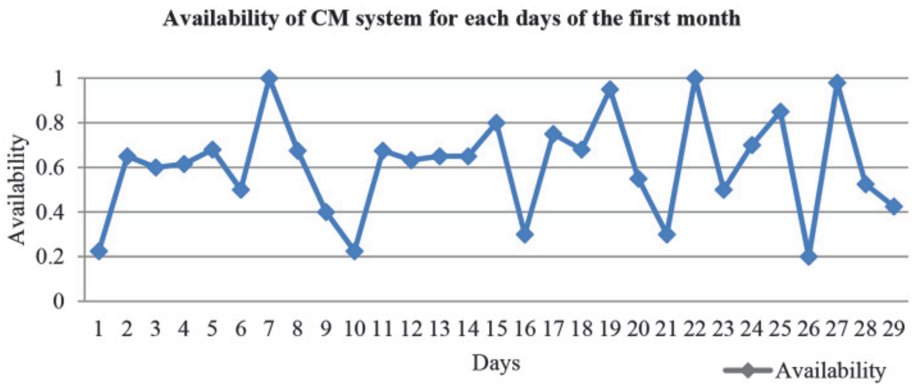


Fig.2: Availability of the CM machine for each day of the first month under study

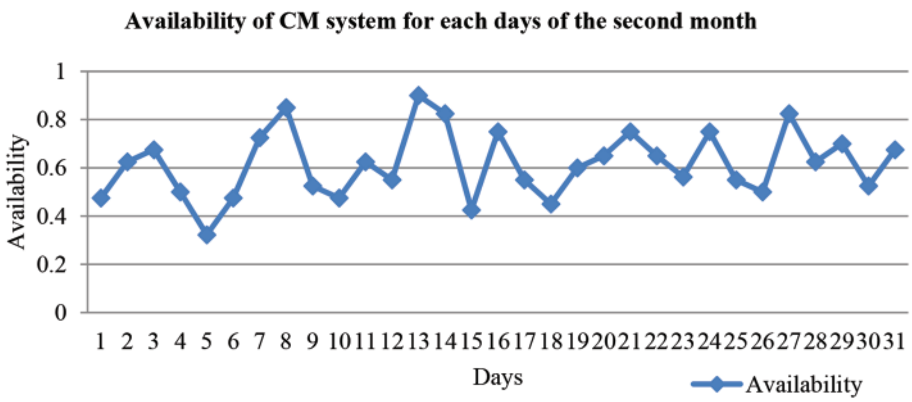


Fig.3: Availability of the CM machine for each day of the second month under study

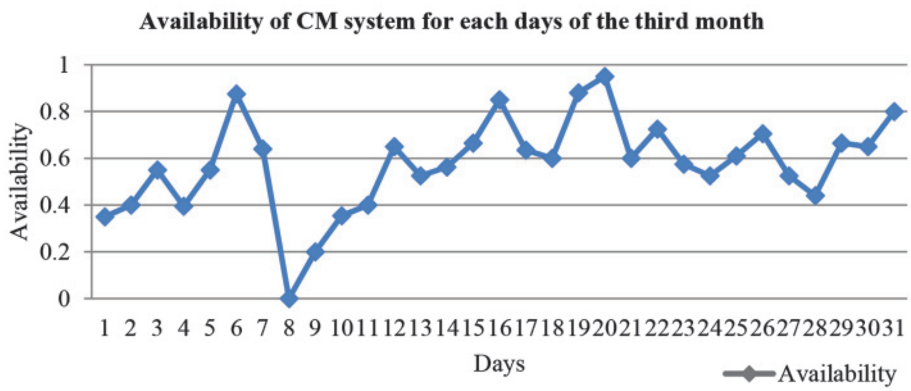


Fig.4: Availability of the CM machine for each day of the third month under study

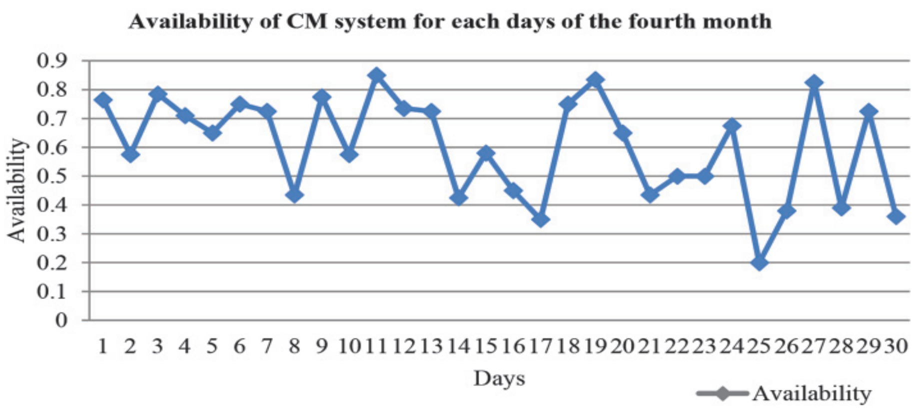


Fig.5: Availability of the CM machine for each day of the fourth month under study

Above figures depict a highly fluctuating machine availability trend for the entire duration of study. This can be further justified by subs-system availability analysis; which may be helpful in indentifying the vulnerable sub-systems.

The Figs.6 to 9 depict average month wise availability of each sub-system of the CM system under study.

Legends:

F/B = Feeder breaker, CM con. = CM conveyor.

Three least available sub-systems for each month under study can be easily identified from the graphs depicted in the Figs.6 to 9.

Fig.6 depicts sub-system availability of CM based system for the first month under study, from which it can be concluded that three least available sub-systems for that month are traction followed by electrical and gathering arm.

Fig.7 depicts that traction is the least available sub-system for the second month under study, followed by conveyor and cutter.

Sub-system availability for the third month under study is depicted in the Fig.8, from where it can be concluded that; three least available sub-systems are traction followed by cutter and electrical.

From Fig.9, three least available sub-systems for the fourth month are identified as: traction, ram car and conveyor.

Therefore, from these identified sub-systems for the overall course of study; few common sub-systems are found; these are traction, electrical, conveyor and cutter. This finding has the match with the outcomes of the miner's perspective as mentioned earlier.

7. Recommendations

7.1. Inspection and maintenance of proper sealing of motors to

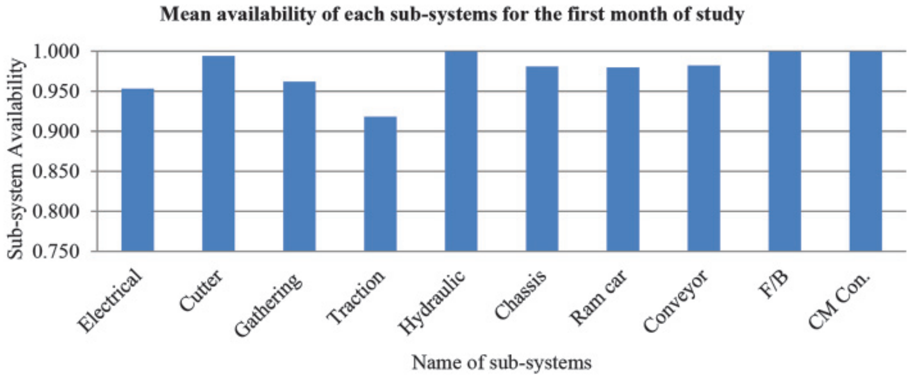


Fig.6: Mean availability of each sub-systems of CM based system during first month

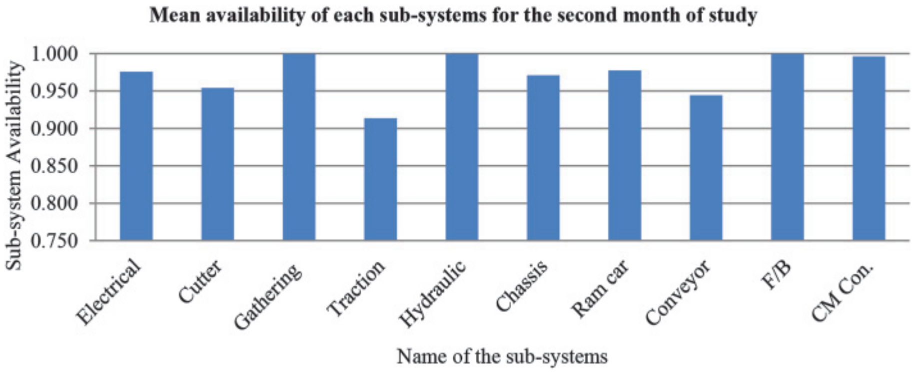


Fig.7: Mean availability of each sub-systems of CM based system during second month

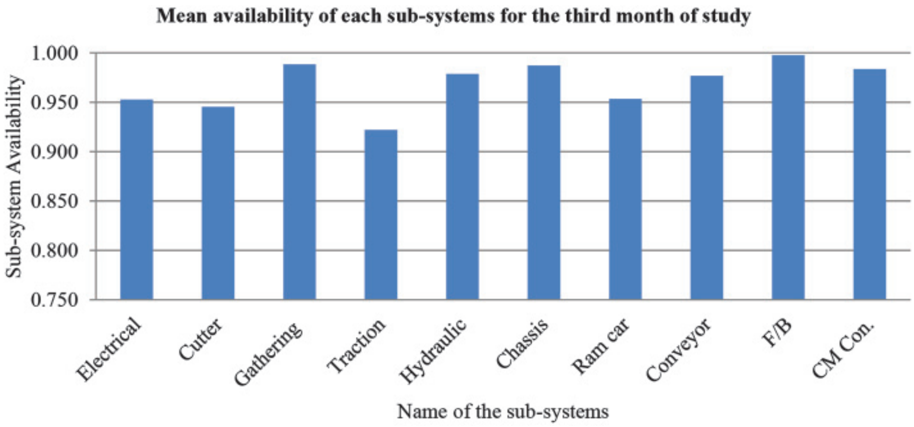


Fig.8: Mean availability of each sub-systems of CM based system during third month

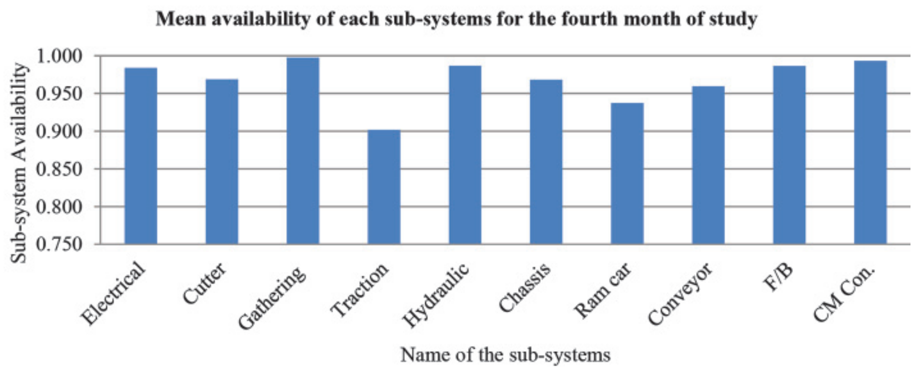


Fig.9: Mean availability of each sub-systems of CM based system during fourth month

prevent water access and electrical faults.

7.2. Mandatory inspection and maintenance of the conveyor belt components during scheduled maintenance hour each day.

7.3. Visual inspection of belt profile and any deflection during production shifts at a regular interval, to reduce the risk of major breakdown and productivity loss.

7.4. Regular pumping of excess water in the maneuverability route of the shuttle car, for smooth and hassle free movement of the machines.

7.5. Regular maintenance of the cutter motor and cutting picks during scheduled maintenance hour.

7.6. Inspection of the cutter picks by the operator before starting the machine; during interim period of the shifts.

7.7. Regular inspection of the hydraulic system to avoid any unplanned stoppage.

7.8. Pre start check during interim of shifts for CM conveyor, Feeder breaker and quad bolter condition to ensure low possibility of any unintentional stoppage.

8.0 Conclusions

This study on CM based underground coal mining system depicts few potent factors contributing towards low availability as well as productivity trend. These findings are supported by the analysis of the recorded data as well as discussion with the mine personnel. From the discussion it was identified that the mucky floor condition is posing the highest challenge towards smooth maneuverability of the machines such as CM and shuttle car, this incident was also supported through analysis. Other sensitive reasons towards low availability trend; as identified through discussion and analysis are: electrical faults, conveyor breakdown, cutter and pick damage as well as hydraulic breakdowns. Based on these findings few recommendations to overcome these issues are suggested, such as; proper and regular maintenance of the motor sealings, maintenance of cutter and pick, inspection and maintenance of belt conveyor, proper pumping arrangements for the underground to remove excess water from the travelling route as well as pre start check of all the important components by the operator. Finally, it can be concluded that this paper can be regarded as the basis to understand the CM based productivity scenario in Indian mining condition and may be helpful in further research to improve the productivity by improving system availability and modifications.

9.0 References

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