Optimization of Continuous Miner Operations in Bord and Pillar Mining

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Abstract - *In Indian underground mines by conventional mining the loss of coal is more and the safety also less so the many underground mines planning to introduction of the use of the Continuous miner in bord and pillar mining method. The Continuous miner technology helps in achieving high production and faster rate of extraction with safety. The continuous miners use the shuttle car to transfer the coal from face to feeder breaker, quadbolter for bolting operations by using these automobiles and remote controlled continuous miner hence the man power is less and productivity will increase and safety is more.*

The present study has been aimed for optimizing continuous miner operations and optimizing the continuous miner utilization under different conditions.

Key Words*: *Optimum replacement models, Tramming speed, Bolting operation.

1. INTRODUCTION

In underground mining, first and foremost in the modernization process are the machines that extract coal primarily the continuous and long wall miners.

First introduced in the late 1940's, continuous miners provided a quantum leap in the speed and efficiency of extracting coal. Modern versions operate on basically the same principal as their predecessors using a large rotating steel drum in 1967 manufactured by Jeffrey manufacturing company.

The drum is equipped with tungsten carbide steel 'teeth' or cutting bits to cut the coal. Continuous mining currently accounts for about 49% of total U.S. underground coal production each year.

Standard continuous miners can extract coal at a rate of up to 38 tons a minute depending upon the seam thickness. New, more powerful continuous miners are highly productive and are remotely controlled being designed for a variety of seams and mining conditions.

These make possible even fuller recovery of the available coal, while removing the machine operator further from the working area.

2. LITERATURE REVIEW

Introduction

To achieve the mass production in bord and pillar mining the implementation of continuous miner is necessary. The continuous miner used to cut the coal and transferred to the shuttle car to unload.

Bord and pillar mining

The following methods are commonly used in bord and pillar method for development and depillaring using continuous miner:

Development

1. Bord and pillar method

Depillaring

1. Split and Fender system
2. Nevid method of mining

Continuous miner

A continuous miner is a large steel drum equipped with a tungsten carbide teeth that scraps the coal from the face. It is used along with the quadbolter, shuttle car and LHD's. The continuous miner accounts about 45% of underground production, and also utilize conveyors to transport the removed coal from the seam. The remote controlled continuous miners are used to work in a variety of difficult seams and conditions and robotic versions controlled by computers are becoming increasingly common

Types of continuous miner:

The continuous miner product range is segment by mining height requirements into three machine classes for low, medium and high-seam applications.

- 14CM series Continuous Miner
- 14CM series Continuous Miner
- 12HM series Continuous Miner (Ref: 7)

Equipment used with continuous miner

S.NO	Equipment	Quantity
1	Shuttle cars	2
2	Quad bolter	1
3	LHD	1
4	Feed breaker	1

In some mines due to the presence of difficulties the efficient utilization of CM and other equipment is not possible. He the production is not required according to the planned scheduled. To achieve maximum utilization some of the improvements should be done.

3. Overview of the mine

Name of the mine	Venkhatesh khani- vk7 shaft
Area	Rudrampur, kothagudem area, SCCL, Telangana.
Seam thickness	King seam (5.5-10.5)
Seam gradient	1 in 7.5

Location map of vk-7 shaft

(Ref . 010)**Method of extraction in vk-7 mine**

Fish bone Method: The method involves extraction of coal is done by making split in the pillar and slices using continuous miner in level direction first and then driving a push out in the dip direction. A Diagonal line of extraction of pillars is maintained during the extraction of coal and sequence is so adopted to allow the caving of the roof in the dip direction.

4. Development of methodology
RESEARCH OBJECTIVES

- **To ensure optimum utilization of continuous miner**

1. Maintenance planning and optimal replacement of CM.
2. Bolting upto date.
3. Improving the bolting operation.
4. Improving the tramming speed of CM and Shuttle car.

Maintenance planning and optimal replacement:
Optimal replacement models

It is necessary to be able to identify which subs should be considered for preventative replacement, and which should be left to run until they fail. If the sub is a candidate for preventative replacement, then the subsequent question to be answered is: What is the best time?

Replacement problems (and maintenance problems in general) can be classed as either deterministic or probabilistic (stochastic). Failures of sub assemblies are according to a stochastic process.
In determining when to perform a preventive replacement, we are interested in the sequence of times at which the replacement actions should take place. Andrew K.S Jardine and Albert H.C Tsang developed stochastic preventive replacement models that are able to determine optimal preventive replacements intervals of items subjected to breakdown.

Replacement model one

Optimal preventive replacement interval of items subjected to breakdown by Tsang A and Jardine A

An item, sometimes termed a line replaceable unit (LRU) or part is subjected to sudden failure, and when it occurs the item has to be replaced. Since failure is unexpected, it is not unreasonable to assume the failure replacement is more costly than preventive replacement.

In order to reduce the number of sub failures, preventive replacements can be scheduled to occur at specified intervals. The objective is to determine the optimal interval t_p between preventive replacements in order to minimize the total expected replacement cost per unit time this is shown is *figure* . However a balance is required between the amounts spent on the preventive replacements and their resulting benefits.

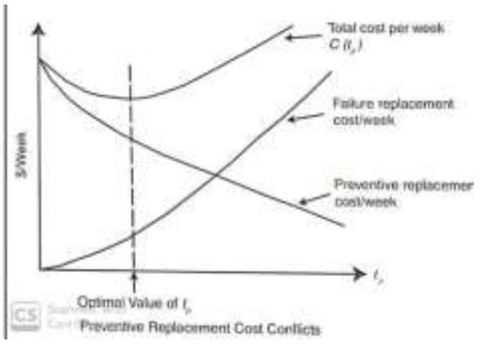

Figure-1 preventive replacements cost conflicts

The replacement policy is illustrated in figure.The goal is to perform preventive replacement at constant optimal intervals of length tp, irrespective of the age of the item, and failure replacement occur as many times as requires in interval (0,tp)

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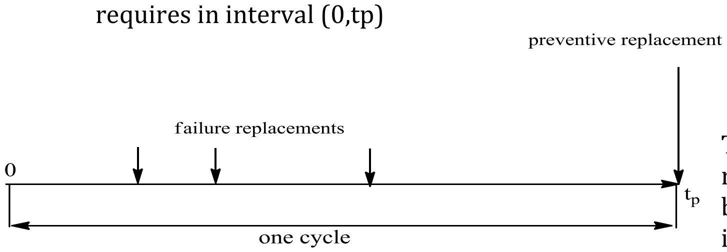


Replacement cycle: constant-interval policy

Figure-2 replacement cycle: constant- interval policy

(Ref: 3 Tsang at el; 2006:50)

Acronyms used in model

1. Cp is the total cost of a preventive replacement
2. Cf is the total cost of a failure replacement
3. f(t) is the probability density function of an items failure times
4. tp is the constant intervals length of the preventive replacements, irrespective of the age of the item, and the failure replacement occur as many time as interval (0,tp)
5. C(p) is the total expected cost per unit time for preventive replacement at interval of length tp

Model formula

$$(t_p) = \frac{C_f + CC_f\, H(t_p)}{t_p} (1)$$

(Ref:3 Tsang and Jardine)

Discussion of the model

Equation (1) is used to determine the total expected cost per unit time for preventive replacement at intervals of length t_p .For every length t_p a different expected cost will be calculated.

After further experimenting and studying of Tsang and Jardine's model a serious flaw was discovered. When a component failure occurs a repair is done to fix the failure but, there exist a possibility that preventive maintenance could be scheduled for that component shortly after the replacement was done. If that was the case preventive maintenance will loose its advantage and actually increase maintenance cost due to over- maintenance.

The other key issues with the component preventive replacements in this model was that only one variable was being used to estimate the health of an item as described by its probability of failure. Even a novice that don't know anything about maintenance of mining equipment will tell you that many factors contribute to the health of a component and that the probability of sub failure is not adequate information to describe a real life failure occurrence.

The model should be solved and on the results of this model an analysis should be done to determine where the model does represent the current failure and replacement patterns

Replacement model two

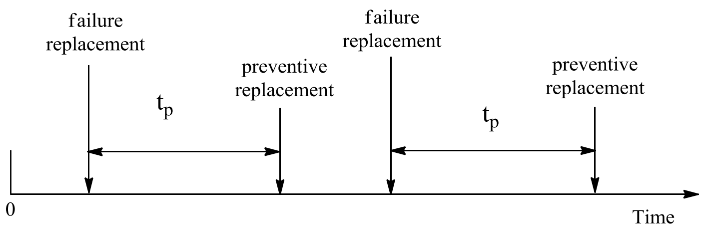
Optimal preventive replacement age of an item subjected to breakdown By Tsang and Jardine

The difference in this model to that of the previous model is that instead of making preventive replacements at fixed intervals, with the possibility of performing a preventive replacement shortly after a failure replacement, the time at which the preventive replacement occurs in this model depends on the age of the item. When failures occur, failure replacements are made.

When a preventive replacement takes place the replacement actions returns the equipment to the "as new" condition, thus continuing to produce exactly the same service as the equipment that has just been replaced when it was new.

Again the problem is to balance the cost of the preventive replacement against their benefits, and this is done by determining the optimal preventive replacement age for the item to minimize the expected cost of replacement per unit time.

The preventive replacement for a component is done only if the component has reached a specific age t_p. Failure replacements are done when necessary. This is shown in figure



Replacement cycle:age base policy

Ref: 3(tsang at el; 2006:50)

Figure-3 replacement cycle:age base policy

There are two possible cycles of operation:

- Cycle one being determined by the item reaching its planned replacement age tp.
- The other cycle being determined by the equipment ceasing to operate due to a failure occurring before the planned preventive replacement time.

Acronyms used in the model

1. Cp is the total cost of a preventive replacement
2. Cf is the total cost of a failure replacement
3. f(t) is the probability density function of an items failure times
4. tp is the specific age of the component at which a preventive replacement takes place
5. R(tp) is the probability of a preventive cycle
6. M(tp) is the expected length of failure cycle
7. C (tp) is the total expected cost per unit time for preventive replacement when the component is at age tp.

Model formulation

$$C(t_p) = \frac{C_p X R(t_p) + C_p X[1 - R(t_p)]}{t_p X R(t_p) + M(t_p) X [1 - R(t_p)]} \qquad (2)$$

Ref: 3 (Tsang and jardine)

Discussion of the model

Equation (2) is used to determine the total expected cost per unit time for preventive replacement at intervals of length t_p During literature study of this model it became clear that this model could be a candidate model for solving the problems maintenance management was facing. The reason for this was that this model was able to specify for each component the time at which the preventive replacement should occur depending on the ages of the component. This model will be solved and the solutions will be compared with the replacement model in above Chapter to verify if the solutions are consistent and reliable.

Improving the bolting operation: As mentioned above the maintenance and replacement strategies also applicable in Quadbolter.

Total productive maintenance

TPM is a people–centered methodology that has proven to be effective for optimizing equipment effectiveness and eliminating breakdowns. Routine servicing and minor repair of their machines creates a sense of ownership of the facility or machine they work on. To achieve zero breakdowns, hidden defects in the machine need to be exposed and corrected before they have deteriorated to the extent that they will cause the machine to break down. Its emphasis is on early detection of wear out to prevent in service failures. In vk 7 shaft the main problems encountering in the Quadbolter are rig seals damage and oil leakages are more.

Improving the tramming speed of the CM and Shuttle car

The tramming speed of the CM and Shuttle car are very important considerations while talking about Utilization of continuous miner. The lower tramming speed of shuttle car causes the CM to wait for shuttle car to unload the coal on it.

Tramming routes: A direct relationship between the tramming route distances and the average away times has already been established. It is therefore important to keep the tramming as short as practically possible. Not only the distances be kept minimal the following factors should be considered when designing or determining tramming routes.

Floor condition: Bad floor conditions can be as a result of an uneven floor (attributed to geological conditions or floor that are not awept), poor water drainage, and steep gradient. These conditions may significantly reduce the life of the cars' components and consequently cause premature failure, or the cost per ton of the operation may increase due to losses in efficiency and productivity.

Belt extension: To maintain overall short tramming distances, it is important to schedule a belt extension effectively. As the working moves no of pillars splits or belt extension should be done to reduce the tramming distance and time. The maximum average away time that should be obtained at any particular time to reach the set production is 75 seconds.

Cable management: The cable management system is very important in any mine because of the heavy machinery. And the spare cables are not available in the mine.The idle handling of cable of CM should be well protected when the CM is in tramming to return because damage of cables may effect the working time and production.

5. Field observations

As mentioned in the above in above chapter to ensure optimum utilization on CM operations the sub objectives are very important and investigated. The reason was breakdown, shortages and uptime of machinery is very essential for optimum utilization. The old workings breakdown data and uptime data is available. The old workings breakdown data and uptime data is available.

Maintenance planning and optimal replacement

As mentioned above the two replacement models are important to avoid breakdowns and to reduce the cost. As in model one the preventive replacement model objective is to objective is to avoid breakdowns of CM and to determine the optimal time interval between sub replacements of CM. A preventive replacement eliminates the cost of the sub replacements cost when breakdown is occurred.The model two optimal replacement model by Tsang and jardine takes age the age in to the account. And it is used to replacement time of the parts of CM.

Old breakdown details of CM given below

S.no	Classification of breakdown	percentage
1	Electrical problem	7.65
2	Cutter problem	11.32
3	Conveyor problem	4.1
4	Gathering problem	5014
5	Traction	2.47
6	Hydraulic	24.32
7	chassis	0
	Total	100

Table-1 breakdown details of CM

Breakdown, Ideal, Working Hours (percentages) is below

s.no	month	Percentage(%)
1	Breakdown hours	6.32
2	Ideal hours	37.47
3	Working hours	56.21

Table-2 breakdown details of CM per month

Improving the bolting operation

Supporting the area in the CM panel is very necessary because of voids are created by working. As like in breakdown in CM the breakdown in Quadbolter also have impact on working of CM. The Quadbolter need a preventive maintenance to avoid the sudden breakdown or failure of any parts of it. The main failures occurring in the quadbolter are failure of rigs(bolter), and oils.

Breakdown, Ideal, Working Hours (percentage) of Quadbolter:

s.no	month	Percentage(%)
1	Breakdown hours	9.4
2	Ideal hours	41.6
3	Working hours	50.00

Table-3 breakdown details of Quadbolter

Improving the tramming speed of CM and Shuttle car:

As mentioned in above chapter the tramming speed of the machinery is important. In vk 7 mine the speed of the machinery is reduced due to coal as a floor, watery, sluggish roadway. The actual tramming speeds of CM and Shuttle car are given below.

S.no	machinery	Low-high m/min
1	Continuous miner	4.6-19.8
2	Shuttle care	0-8

6. Analysis and Evaluation of Results

Analysis and evaluation of results for maintenance planning and optimal replacement

Tsang A and Jardine A designed two replacement models that were able to calculate the optimal time intervals to perform preventive replacements. Model one used a fixed interval approach. The model derived fixed intervals that specify when to perform preventive replacements. Their second model used a unit age base approach to determine the optimal time to perform preventive replacements.

Model one: The goal of the replacement model is to decrease the number of sub failures. This can be achieved by scheduling preventive replacements at fixed intervals. A balance is required between the amount spend on preventive replacement and their resulting benefits, that is reduced failure replacement.Each sub was investigated individually to avoid breakdown and the results are obtained below.

Sub Assembly	Optimal replacement interval
Traction drive assembly	2 years
Traction motor	2-3 years
Gathering motor	2 years
Gathering gear box	2-3 years
SCR bridge	2 years

Model two: The goal of the second replacement model is similar to that of the first replacement model, to decrease the number of sub failures. The main difference between the model one and model two was that model two specifies the main interval at which the preventive replacement should occur depend on the age of the sub. The optimal age to perform a preventive replacement was determined by the lowest cost as compared to model one over a years.

Sub Assembly	Optimal replacement age
Traction drive assembly	2 years
Traction motor	2 years
Gathering motor	2 years
Gathering gear box	2 years
SCR bridge	2 years

Although the replacement intervals and replacement age show similar results, the results of model two should represent replacements more realistic. This is explained by the traction motor.

Model one advices that the optimal replacement interval for the traction motor should be every 2-3 years. But if a failure occurs before the scheduled replacement a failure replacement will be necessary. If management stays true to the preventive replacement schedule there exists a possibility of performing a preventive replacement shortly after a failure replacement. This will results in over-maintenance.

To avoid such an occurrence the replacement schedule of model two should rather be used. Model two advise that when the Traction motor reach an operational age of two years and no failures occurred during that time, the Traction motor should get replaced. But if the Traction motor failed during that period the sub should be replaced. To advantage of model two above that of model one results is that when a preventive replacement takes place the replacement actions returns the equipment to the “as new” condition.

Analysis and evaluation of improving the bolting operation

As mentioned in above cause of breakdown of quadbolter is rigs and oil problems. To eliminate the breakdown and improve the bolting operation the Total productive maintenance methodology is effective.

To eliminate these failures

- Preventive maintenance tasks are undergo before a failure occurs.
- And the availability of the required rigs are important.
- Oil changes are maintained accordingly
- To reduce the maintenance works the workers should be well trained.

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Analysis and evaluation of improving the tramming speed of CM and Shuttle car

As discussed above to improve the tramming speed of the CM and Shuttle car can be achieved by:

Tramming routes- a long distance of tramming cause more time CM wait to load so the tramming routes of the shuttle car are designed well and the turning radius of the tramming route should be kept minimum.

Floor condition- the coal is present as a floor in the king seam so the skidding of machinery is more due to water from strata and water hoses in cutting boom of CM in the CMP panel so, the installation of small size pumps at face and wherever necessary are required.

7. CONCLUSIONS

The two models were studied and both models yield sub replacement schedules. In that two models the second model by Tsang and Jardine was found to be the better suitable models for the maintenance in VK-7 mine.

The optimal preventive replacement for subs of the CM can now be planned according to the new replacement schedule. The replacement schedule is determined by average breakdowns.

The improvement in bolting operation is can be done by eliminating breakdowns by total productive maintenance (TPM) strategy and keeping the required materials when breakdown is occurred.

Tramming speed of the CM and Shuttle car are studied in the above chapters. The tramming routes should be prepare by considering the unload distance of shuttle car from face to feeder breaker. And the newly prepared tramming routes should be well maintained.

Future scope

In the project we studied only about utilization of continuous miner for optimum utilization. And other objectives like, improving the production and productivity also can be improved by changes in the continuous miner and also by additional shuttle car when one is at maintenance other two will be at working.

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