AIJREAS VOLUME 2, ISSUE 2 (2017, FEB) (ISSN-2455-6300) ONLINE
ANVESHANA'S INTERNATIONAL JOURNAL OF RESEARCH IN ENGINEERING AND APPLIED SCIENCES

CHARACTERIZATION OF PULVERIZER IN REFERENCE TO INDIAN THERMAL POWER PLANT

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ABSTRACT

In this thesis preventive maintenance scheduling aspects of thermal power unit have been studied. Over the years preventive maintenance theory has been significantly developed and a large number of models have been presented in the literature. Despite this there is still the opinion that the gap between theory and practice remains very large in maintenance management. This might be due to the fact that most of the work done aims at theoretical model development and plant level studies are few. This motivated the adoption of a case based approach for this thesis. Simulation models have been developed for a single pulverizer and the entire fuel system, in FORTRAN on a PC-AT using discrete event framework. The opportunistic maintenance policies have been evaluated using the single pulverizer model and the proposed policy has been found to be better than other policies. The performance of this policy under the existing man-power restriction has been studied using the model for the entire fuel system. It has been found that the OM policy promises significant reduction in generation.

Index Terms— *Preventive maintenance theory, Maintenance requirement of thermal power units, Construction of ball mill and bowl mill.*

INTRODUCTION

Industrial Organization use equipment and employ labour to convert raw materials of relatively low value into finished products of higher value with the objective of earning an adequate profit and return on investment. Investment on the plant and equipment occurs from its conception to its commissioning and if all goes well the return on investment starts when the plant comes into use and continues until the plant is disposed off at the end of its useful life. The maximum profit, the time from conception to commissioning should be as small as possible while the useful operating life should be as large as possible.

Energy (i.e. Electrical power)is a very basic necessity of human life. The term energy is immensely associated with generated electric power. There are various sources of power usable in our daily work. Out of these, thermal power is one of the major conventional resources. Thermal power is mainly available by burning coal, low diesel oil, natural gas etc. These are effectively converted into electrical power thereafter. Basic resources of the electrical power in the world are mainly thermal power, hydroelectric power and nuclear power. In our country, more than 65% of power requirement is met by thermal power. During independence we had installed capacity of power of about 2300 MW. Current installed capacity has gone up to 200 thousand MW. Of this around one and quarter lakh MW is available from thermal power plants. Large numbers of thermal power plants have been constructed in the post independence period due to the fact that the basic raw material, coal is abundantly available indigenously.

CONSTRUCTION OF BALL MILL

The Pulverizer is the most critical element in the coal based thermal power plant. Before going to in depth study of pulverizer performance I shall look into its components and mode of construction. The Ball mills which are used up to 200 MW boilers are taken first for review.

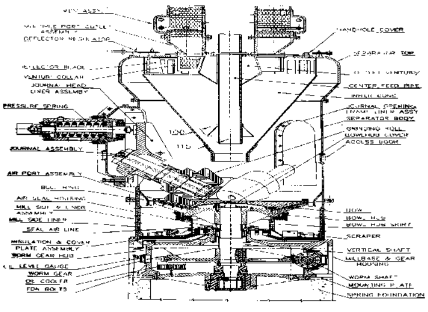
Vide diagram of the Ball mill. The Ball mill housing comprises all the elements of the mill except the driving motor for the mill, which lies apart from the mill housing. The mill is run by a reduction gear box which is mounted on the bed of the mill housing and coupled with the driving motor. The reduction gear box rests at the bottom of the housing and constituted of bevel and helical gears. It transmits power to the mill from the motor at lower speed. The output shaft of the gear box is coupled to the yoke stem by flange coupling. Gear box input shaft coupling is Wellman Bibby coupling. The upper side of the yoke is suitably machined and holds the lower grinding ring. They are assembled with keys having keyways in both. The grinding balls are placed on the lower grinding ring. In 8.5E mill there are eight spherical balls of 750 mm diameter made of Hi-chrome alloy steel. The driving motor rotates the lower grinding ring fitted in yoke having the 8 numbers of spherical steel balls which grind the coal to powder form for feeding into the boiler furnace. Above the steel balls upper grinding ring is placed in the mill housing. The upper grinding ring should not come in contact with the balls to avoid high erosion due to metal to metal contact between these. On the upper side of the upper grinding ring, the spiders are fitted with the help of keys in keyways in these elements. On the spider, loading cylinder is placed which is connected to loading shaft for exerting pressure for grinding the coal. Pressure is developed in the loading cylinder shaft by oil/ gas that is supplied to the cylinder by the pipe lines. Stirrups are placed on the spider. Swivels are located in the stirrup cups and connected to internal lever of loading cylinder and spider for applying pressure for grinding coal.

The classifier housing starts from the periphery of the lower grinding ring. It is of cone Section having throat in segments (throat is made from a number of plates). The raw lump coal enters the mill housing from the bunker by a central pipe passing through the upper turret of mill housing and falls on the lower grinding ring and is crushed by the spherical steel balls between the grinding rings. Primary air enters the mill housing from lower part of the mill housing and moves upward carrying the pulverized coal powder with it. The air has positive draft (about 10 – 15" of water column) in the mill housing. The outer most part of the classifier housing has adjustable vanes. The powder coal of required mesh size with air passes through the adjustable vanes and goes to the feeder through fuel piping for throwing into the boiler furnace. The over sized coal and non – grindable matters (tramp iron, metal ores) move towards the perimeter of the mill housing due to centrifugal force act upon those and then they fall down wards on the edge of the lower end of the classifier housing. Most of the oversized coal returns to the pulverizing zone. The tramp iron and non-grindable matters are removed by the moving scrapper plates fitted on the yoke and sent to the pyrite box.

At the inlet of the classifier housing the coal and air mixture is given a spin by the rotating deflector plates. The spin velocity depends on the angle of the adjustable deflector plate. At the lower end of the yoke, there is a seal air casing. High pressure Air is sent to the seal air casing to prevent leaking of coal air mixture from the pulverizer zone of mill housing and enter into the gear box and bearing housing to contaminate and erode the gears and bearings.

CONSTRUCTION OF BOWL MILL

Bowl mills are used for higher feed rate in 200 MW and 500 MW boilers. Bowl mills are more economic than the ball mills and consume less energy for the same output rating. In bowl mills roller grinders are used in place of spherical balls used in ball mills. Vide diagram. In BHEL make Bowl mill XRP- 1003; four rollers are used for grinding coal. Coal is crushed by the rollers between the bullrings. The lower bullring is rotated by worm and worm shaft assembly of the bowl mill gear box, which is coupled to the driving motor. The gear box has a lower output speed. The grinding rollers are connected to the journal assemblies. Rollers are given required pressure for grinding the coal by applying torque to the spring in the journal assembly. The other mechanisms in the Bowl mill except pulverizing and loading are similar to that of Ball mill.



BOWL MILL CROSS-SECTION

PRINCIPLES OF PULVERIZER OPERATIONS

- Coal is fed to the center of the Pulverizer on to a revolving grinding ring. Centrifugal force causes the coal to travel towards the perimeter of the grinding ring. The coal passes between the grinding rings and spherical balls/ rollers, which impart the force necessary for grinding.
- Heated air enters the mill housing near the lower grinding ring and directed upward around the mill housing outside diameter and separator body annulus by the rotating vanes. It moves upwards and into the deflector openings in the classifier at the top of the inner cone and then goes out through the vanes/ ventury and multiple port outer assembly.
- As the air passes upward around the mill housing/ bowl, it picks up the partially pulverized coal particles and carried up through the deflector openings of the classifier. The deflector blades in the openings cause the coal air mixture to spin with in the inner cone. The angle of the blades determines the velocity of the spin and the resulting fineness of the finished product. Heavier pulverized coal particles are returned through the inside of the inner cone to the bowl grinding zoan for further grinding. Coal that is pulverized to the desired fineness leaves the pulverizer and enters the fuel piping system.
- Any tramp iron or foreign material difficult to grind is carried over the top of the housing / bowl where it drops through the air stream and rotating vanes to the mill bottom. Pivoted scrappers attached to the yoke sweep the tramp iron to the tramp iron discharge opening. The tramp iron spout is fitted with a valve. Under normal operation this valve remains open and material is discharged into a sealed pyrite hopper. The valve is closed only while the hopper is being emptied.

- Closing of the valve on the tramp iron spout for an extended period, material normally discharged will be retained in the mill side housing and be ground by the scrappers, scrapper guards and holders.
- This produces excessive wear on these parts and creates a potential fire hazard. If coal is discharged in to the pyrite hopper, this indicates over feeding, too little pressure on the balls/ rolls, too low an air flow or too low a pulverizer outlet temperature.
- Excessive worm pulverizer parts or improper adjustment can also cause coal to be discharged. Excessive spillage indicates that a pulverizer is not functioning properly and steps should be taken as soon as possible to correct the situation.
- The pulverizer operates under positive pressure. A seal air system provides clean air to a chamber surrounding the bowl hub to prevent hot air and coal dust from contaminating the gear box, coupling and bearing housing.
- Seal air is supplied to each journal trunnion shaft to prevent coal dust from entering the journal bearings. Seal air is also applied to each spring assembly to keep it free from coal dust.
- For good pulverizer performance the temperature of the coal air mixture leaving classifier should be maintained as high as possible with in the safe temperature limit of the particular coal. Too high an outlet temperature may lead to a pulverizer fire. Typically bituminous coal may tolerate temperature to 70°C. Sub- bituminous coal may become troublesome with pulverizer outlet temperature exceeding 65°C.
- Environmental conditions may cause changes that would result in lower pulverizer outlet temperatures. A pulverizer may be operated at a temperature below 65°C, provided there is no loss in capacity, coal spillage or high motor current. An outlet temperature below 60°C may not dry the coal sufficiently.
- Pulverizer systems should be designed to perform effectively with a wide range of mixture content and grindability. In order to obtain rated capacity from the pulverizer, it is necessary to have sufficient hot air (air from primary air fan is passed through pulverizer) entering the pulverizer to dry the coal, sufficient pressure on the balls/ rolls to pulverize it and proper setting of the classifier deflector vanes to obtain a fineness reasonably close to that for which the pulverizer is designed. There is a provision to place a fill in ball in ABB make 8.5-E (8 + 1) ball mill, when the existing balls become eroded sufficiently to a certain diameter.
- A gap is maintained between the balls top surface and top grinding ring lower surface to avoid high erosion due to metal to metal contact between those. The gap between these is maintained considering the required size of coal to be sent to the boiler furnace for combustion.

Sub systems of Pulveriser

he Pulveriser is divided into eight nos sub systems, which are as follow

1. Feeder box
2. Mill internals
3. Driving units
4. Loading unit
5. Rejection system
6. Seal air system
7. Lubrication system
8. Others

vailability of a sub system is calculated as follows.

$$\text{Availability} = \frac{\text{UP-time}}{\text{UP time+Down time}}$$

own time = Repair time/Maintenance time

eliability of a sub system is calculated as follows.

$$\text{Reliability} = \frac{e^{-Z} Z^{X}}{X!}$$

Where Z is mean.

Availability and Reliability of Pulverizer components

Serial No.	Description of components	Availability	Reliability
1.	Feeder box	0.98	0.3
2.	Mill internal	0.97	0.7
3.	Driving unit	0.9	0.95
4.	Loading unit	0.98	0.5
5.	Rejection system	0.99	0.75
6.	Lubrication system	0.99	0.9
7.	Others	0.99	0.35

DATA ANALYSIS OF PULVERIZER

Data has been collected for a period of approximately 22 months in between two successive unit overhauls from the Monitoring cell of the plant which keeps track of the outages of various equipment. The data consisted of date and time of Pulverizer stoppage and date and time of completion of maintenance activity, and the reason for stoppage. Taking the end of the unit overhaul as reference point, cumulative operating times at which outages have occurred were calculated. Care has been taken to deduct unit outage time (particularly outages of slightly longer duration) while calculating Pulverizer operating time. This is necessary because during unit outages all Pulverizers are stopped. It can be observed that cumulative operating time plus cumulative down time of all Pulverizers may not match. This is because during a unit outage some Pulverizers may already be down and correction for unit outage was not made for those Pulverizers, whereas for other Pulverizers correction was made. Actually the operating time also includes any stand-by time because when all six Pulverizers are available, one remains as a stand-by. Further due to constraints at other systems, the unit may be performing at reduced capacity resulting in the operation of the Pulverizer system with less number of Pulverizers, Correction for stand-by time could not be made due to lack of information about actual pulverizer operating time. However when the unit performs at reduced capacity operation, the practice was to run five pulverizers at reduced capacity to ensure better firing of the boiler, rather than shutting down some pulverizers. When all the six pulverizers are available, due to the failure of operating pulverizers the stand-by comes into operation and it can be reasonably assumed that all pulverizers spend equal amount of time as stand-by. Anyhow the instance of all the pulverizers being available is few. With all these, it is hoped that not being able to make corrections for stand-by time will not create any serious distortion in the analysis. The analysis has been carried out in three stages. Firstly, downtime analysis has been carried out so as to study the effect of individual subsystems on pulverizer unavailability. Secondly, failure time data analysis has been carried out and lastly analysis has been carried out to arrive at failure time and repair time distribution of the subsystems. These aspects are discussed in the following sub sections

DOWN TIME ANALYSIS

As mentioned during study of "Break up of Pulverizers downtime" table, the total downtime of all the six pulverizers was16266.44 hours resulting in a generation loss of 3.73 percent. To carry out further analysis, each pulverizer has been broken down into its constituent sub systems and down time due to each pulverizer stoppage has been allocated to the corresponding subsystem. The details of down time figures under each category are given in the following table.

As can be seen down time for Mill overhauls tops the list and this constitutes around 28 percent of the total downtime. Though the instances of Mill drive failures, ring breakages and feeder chain break a gas are few, these breakdowns consume huge amount of downtime for their correction. These major breakdowns together constitute around 37 percent of the total downtime. In total Mill overhauls and the above said few major breakdowns constitute around 65 percent of the downtime. However the number of outages due to these reasons is only 18 out of the total of 732. Frequent failure of others ub systems account for remaining amount of the total downtime.

The effect of the major outages as mentioned earlier is due to the operation of the pulverizer system without a stand-by for most of the time (around 65 percent). The effect of these major outages can be made much clearer by dividing the total generation loss of 3.73 percent into two parts, namely, loss during the period when one of the pulverizers is under major shutdown and loss during the other period. In this particular case these losses are 4.90 percent and 1.43 percent respectively. From this it is seen that during the period when one of the pulverizers is under major shutdown, the frequent failures of subsystems have resulted in a loss of 4.90 percent and whereas during the other period the frequent failures components do not have that much effect.

OPTIMIZATION OF OPPORTUNISTIC MAINTENANCE OF PULVERIZERS THROUGH SIMULATION

Pulverizers can be treated as a series system of eight dub systems and the failure processes of the subsystems can be modeled as renewal processes. It has been found that opportunistic maintenance (OM) policies are more suitable for the subsystems of the Pulverizer and simulation is an appropriate method to evaluate the OM policies. For simulation a model has been developed in FORTRAN a PC-AT.

Break -up pulverize downtime		
SUBSYSTEM	DOWNTIME (HRS)	PERCENTS
BUNKER	71.46 (20)	0.44
SEAL AIR FAN	11.08 (2)	0.07
FEEDER :- Feeder chain breakage	2111.17 (6)	12.98
Feeder jamming	100.65 (61)	0.62
Feeder box	1706.64 (72)	10.49
Feeder drive	601.38 (54)	3.7
MILL:- MILL overhaul	4503.25 (5)	27.68
Ring breakage	847.58 (2)	5.21
Mill internals	1183.36 (70)	7.28
Rejection system	607.52 (82)	3.74
Loading units	565.17 (125)	3.47
Mill drive	3114.57 (5)	19.15
Mill gearbox lubricating oil system	91.57 (13)	0.56
PA Fan Main Unit	28.42 (4)	0.17
Bearing lubricating oil system	99.16 (15)	0.61
Coal carrying pipes	496.17 (132)	3.05
Burners	70.02 (39)	0.43
OTHERS	57.27 (9)	0.35
TOTAL	16266.44 (732)	100
(Figures in brackets) indicates number of outages.		

SIMULATION MODEL FOR SINGLE PULVERIZER:

Discrete event framework has been adopted in developing the simulation model for single Pulverizer. It is assumed that the Pulverizer operates simultaneously whenever it is available. It is supposed that repair activity is initiated as soon as a failure occurs. Under these conditions, the process essentially consists of two events, failure and repair completion occurring continuously in that order. The operating time of the Pulverizer accumulates in between the failures. Since the life of the mill ring is approximately 15000 hours and after which the entire pulverizer is overhauled, the simulation process is continued for 15000 hours of operating time and the results are obtained for that run. After this all the components of the Pulverizer are considered as new and the process is repeated for another 15000 hours of operating time. The process is repeated for a number of times and the mean values of the results of all the runs are obtained. The detailed process is depicted in the form of a flow chart.

For each run, the process starts with the Pulverizer being in new condition. That is ages of all the subsystems are kept as zero initially. Failure times for all the sob systems are generated from the corresponding distributions and the failure time of the Pulverizer is equal to the minimum of failure time of the subsystems. The operating time of the pulverizer is incremented by failure time of the Pulverizer. Ages of the subsystems and the number of failures of the subsystems and Pulverizer are updated. Repair time for the failed subsystems is generated from the corresponding distribution and the cumulative down times of the Pulverizer and the subsystems are updated. Since the failure processes of the subsystems follow renewal processes. After every failure the sub systems are as good as new. Accordingly next failure time of the failed subsystem is generated from the corresponding distribution and the failure times of the other subsystems are updated. Next failure time failure time of the Pulverizer is arrived at and the operating time of the Pulverizer is incremented accordingly. The process is repeated continuously till the operating time of the Pulverizer reaches15000 hours. Then the results are stored for the run and the process is repeated for several runs. Finally the mean values of the results of all the runs are calculated.

Simulation model for fuel system (containing a number of Pulverizers): In the present case 6 nos Pulverizers are in the fuel system. The fuel system model of Pulverizers though similar to that of the Single Pulverizer model described above, differs in the logic in many ways. Here also the process essentially consists of failure and repair completion events of the Pulverizers. In the single Pulverizer Model, failure event and repair event occur one after the other sequentially. However in the fuel system model this may not be so. After the failure of a Pulverizer, its repair completion event is scheduled in clock time. Before the repair completion, another Pulverizer may fail and thus the process might not go sequentially from failure event to repair event and so on. In the single Pulverizer model, repair on the failed Pulverizer is taken up immediately. However in the case of fuel system model, due to the limited availability of man power, repair on a failed Pulverizer may not be taken up immediately. Thus two stacks namely repair stack and waiting stack have been created. The repair stack consists of repair activities that have to be initiated as and when the man power is available. Whenever a failure occurs, the repair activity is stored in either repair stack or the waiting stack, as the case may be. When the repair completion occurs, one repair gang becomes available and accordingly one activity from the waiting stack, if there is any is kept into the repair stack. In the case of single Pulverizer model, the possibility of performing OM has to be checked at the time of failure events only. However in the case of fuel system model, the possibility of performing OM has to be checked at the time of failure event and also at the time of repair completion event.

In the single Pulverizer model, Pulverizer overhaul, which is performed approximately after 15000 hours of operating time, was considered as the terminating point for each run. For each run all the subsystems of the Pulverizer being in as good as new condition were considered as the initial condition. The behavior of the Pulverizer was observed between Pulverizer overhauls. However in the fuel system model, overhauls of the Pulverizers have to be included as events occurring in the process.This are so because, generation loss is affected by all Pulverizer downtimes, even due to overhauls.

Since all the Pulverizers are not overhauled at the same time, the system being in zero state (that is, all the Pulverizers in as good as new state) cannot be taken as the initial conditions for each run. In fact, in this case what should be of interest is the steady state or long run value of the objective function. For this purpose, the model has to be run for a very long period of time so that the objective function attains a steady state value, wherein the effect or bias of the initial conditions is eliminated. The same thing can be achieved by dividing the total run length into convenient intervals and then considering each interval as a single run. The final conditions of each run are considered as the initial conditions for the next run. The mean of the results of the individual runs is taken as the simulation result. In this way for each run, different initial conditions are considered so that the effect or bias of the initial conditions is eliminated.

For the present case, it has been observed that the period between two successive unit overhauls is approximately 22 months. Accordingly 15000 hours of clock time has been considered as the length of each run. Simulation exercise has been started with the initial conditions of all Pulverizers being as good as new.
Have been taken as the initial conditions for the subsequent runs. While calculating the mean result of the simulation, results of the first run have not been taken into consideration. The detailed process depicted in the form of a flow chart.

CONCLUSION

On plotting availability and reliability curves of pulverizer subsystems (components), it has been observed that the failure characteristic follows exponential distribution function which reveals inevitable suitability of opportunistic preventive maintenance policy for pulverizer subsystems to bring down the generation loss of the power units effectively. In this thesis preventive maintenance scheduling aspects of thermal power units have been studied. Based on the analysis of constructional and operational features of thermal power units, it has been found that there are two important aspects of thermal power unit maintenance which needs careful planning namely, scheduling of unit overhauls and scheduling of preventive maintenance on auxiliaries in between unit overhauls. The distinctive feature of these two problems is that schedule of the unit overhauls is arrived for all the units in the system simultaneously, considering the system constraints. Respective power unit managers have little say other than supplying relevant information in the task of deciding the actual schedules. As opposed to this, decision making regarding the scheduling of preventive maintenance on auxiliaries is completely in the hands of respective unit managers and preventive maintenance work on the auxiliaries is scheduled considering the factors/constraints at the unit level.

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